

Metallurgical & Chemical Engineering

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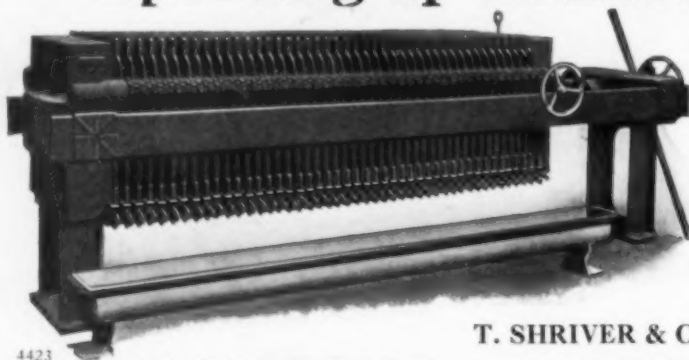
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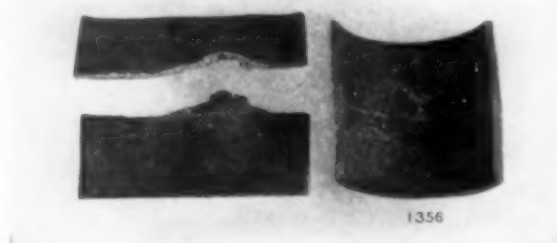
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Why Play to the Galleries?

It never rains but it pours. If it is not a new and revolutionary invention in oil chemistry, it is at least an announcement of one. And the daily newspapers seem to be happy that besides the war they have something else they can write about without being troubled by scruples that come from too much knowledge.

At the February meeting of the American Institute of Mining Engineers in New York, Dr. Walter O. Snelling presented in the Petroleum and Gas Section informally a paper on gasoline from synthetic crude oils, relating some surprising and interesting observations. The paper was discussed in open meeting. An abstract was published in our last issue. The formal paper in full will be published in the next *Bulletin* of the Institute.

A fortnight later, on the first of March (it was not the first of April) the daily newspapers printed a remarkable interview with Secretary Lane in Washington, on two now celebrated oil inventions of Dr. Walter F. Rittman of the Bureau of Mines, and in the string of delightful newspaper stories which followed, an American dyestuff industry was created on paper under the protecting wings of the Bureau of Mines.

It is a pity that no official technical information was given out at the same time. We hope that Dr. Rittman's expectations will be realized—whoever knows him likes him. But whatever the future may bring, it is like a blow to the standing of the American chemical profession that the announcement of achievements of such alleged importance should have been made in a manner so unconventional according to professional standards. Claims should not be made unless proof is produced at the same time. First with radium and now with oil, the Bureau of Mines has been rather unlucky in the choice of its press agents.

A Spectacular Spelter Market

The daily market report on spelter has made interesting reading for a couple of months. It was anticipated, of course, that spelter would rise after the war started and authorities freely predicted seven-cent spelter. The predicted price has been exceeded and ten-cent spelter realized. The explanation lies in the fact that our domestic production and consumption have been about equal; and with foreign production greatly curtailed a tremendous export demand has been added to domestic needs. Add to this a certain hysteria that is likely to accompany such conditions, and we have the explanation of a runaway market. The inevitable slump has come and prices have receded, but will probably remain high during the war.

A review of average annual zinc prices for thirty

years past shows that the highest prices at New York was roundly seven cents for 1912. Prior to that the high average was about six and two-tenths cents for 1906. In no other year was the average annual price as high as six cents. Present prices are without comparison. The highest price ever paid for Joplin concentrates was reached early in February, when the basis for 60 per cent concentrates was \$70 per ton, with premium grades bringing a higher price. Utah and Colorado operators have taken advantage of the situation and have been shipping low-grade ores. Of course such conditions could not last long. They work temporarily to the benefit of ore producers, but are not so acceptable to smelters who have to buy ore at a high price with the prospect of being able to sell the metal therefrom at a time when prices have receded from their high level. It was for this reason that zinc-ore producers who were without smelter contracts found it impossible to sell their ores at any price.

Illuminating Pig Iron Statistics

The official statistics of pig iron production are presented in such detail that some interesting conclusions can be derived as to trade movements and the character of material produced from the iron. The production in 1914 was 23,332,244 gross tons, making the year's tonnage 24.6 per cent under that of the record year, 1913; 1.4 per cent under that of the lean year, 1911; but 46.3 per cent in excess of the tonnage in 1908. So rapidly has the iron and steel industry grown, however, that the 1914 output was greater than that of any year preceding 1906, even though 1905 in its time was a year of great activity, and the output was more than quadruple that attained in 1886 or any preceding year.

The banner year for the Bessemer process was 1906. In years of relatively full demand, like 1912 and 1913, the character of the steel process employed is necessarily dictated largely by the facilities available, while in a year of light demand like 1914 the preferences of buyers have more influence, hence the following comparisons between 1906 and 1914 are quite illuminating:

PIG IRON PRODUCTION			
	1906	1914	Change
Bessemer	13,840,518	7,859,127	-33.2%
Basic	5,018,674	9,670,687	+92.8%

Included in the tonnage reported as "Bessemer" is about 200,000 tons of low phosphorus iron, the precise output of which in 1914 has not yet been separately reported.

Of the Bessemer and low-phosphorus pig iron produced in 1914, 5,467,687 tons, or 69.5 per cent, was delivered molten, indicating almost universal and continuous employment of direct metal, except as prevented by the necessity of casting Sunday metal and metal for stock, as well as the shipment of iron between works under allied ownership. Of the total production of Bessemer and low-phosphorus iron in 1914, only 527,905 tons was made for sale. Doubtless this comprised nearly all the low-phosphorus iron, the remainder being

almost exclusively iron sold for the manufacture of ingot molds. The major part of this iron is delivered molten, although sold, and with two additional plants now being built to use direct metal in making ingot molds the vogue of this process will become practically universal, even though the ownership of the mold foundries is entirely different from that of the furnaces which, under long-term sliding-scale contracts, furnish the molten pig iron. In the case of basic iron 6,436,146 tons, or 66.5 per cent, was delivered molten, leaving 3,234,541 tons that was cast, doubtless all in chills. There was 1,479,721 tons of basic iron made for sale, and it is doubtless accurate to deduct this tonnage, as having been cast, leaving it that 8,190,966 tons of basic iron was made for the consumption of the producers, all but 1,754,820 tons of this having been used direct, making 78.6 per cent of the makers' production used direct, an even larger percentage than obtained in the case of Bessemer iron.

A Suggestion in Patent Reform

Previous comments in this journal on needed reform in the United States patent system have made it apparent that the objections to our patent procedure lie not so much in the organic law as in the methods of enforcement of the contract between the government and the individual. In the development of our system it has suffered from the same practices that have received public disapproval in ordinary court procedure. Legal technicalities have supplanted in importance the economic aspects of a case, and legal form and procedure have almost attained the dignity of an end instead of a means.

The abuses which have thus found their inception and growth in the practice of adjudicating patent rights have led to the suggestion of a special court of patent appeals with revised rules of procedure and power of final decision. Even this excellent suggestion, however, concerns itself with improvement in the system *after* the patent has been granted, and offers no relief from obvious deficiencies in the system prior to and including the actual grant. The point is that probably much of the trouble now following the grant of a patent might be obviated by greater care in the granting.

Under present conditions a metallurgical or chemical patent in litigation has not received the careful attention of experts until it is called in question. Then it becomes the subject of a long investigation, and expert testimony is brought forward in great volume. The question arises: If experts are deemed necessary to settle a point in litigation, might they not be of equal value in passing scientifically on applications for patent? If, instead of submitting a patent to experts after it has been granted, it were subjected to scientific examination before granting, the prospective patentee might be relieved of much expense, delay and trouble, and would not feel that he had been deceived as to the nature and value of the covenant between himself and the government. Hoover comments on this phase of the matter in his book on Concentration by

Flotation, saying that "if the courts deprive him (the patentee) of the benefits definitely promised, someone has blundered. Every legal case in which the patents of one litigant are declared invalid is an indictment of the most serious nature against the system."

Another benefit that might result from scientific examination of patent applications would be the rejection of many supposed novel ideas of alleged usefulness. Many of these are scientifically unsound and claim results that are practically impossible of achievement. They merely clutter the record. Others contain alleged improvements and are often introduced by patent pirates and leeches. It is recognized, of course, as Hoover says, that "a new metallurgical process never springs fully developed from the brain of one person," and consequently many of the improvements are valuable. On the other hand, one has only to review the patents and litigation in one subject, such as flotation, to feel that if scientific experts reviewed the applications, many of them might not be granted. The situation would be freer from complications and progress in the industry would not suffer.

The Steel Corporation's Operations

Probably there was nothing occult in the coincidence that the thirteenth calendar year of the United States Steel Corporation's existence proved to be its worst in point of earnings. The earnings, \$71,663,615, were not only the lowest, but were only 44.5 per cent of the earnings reported for the Corporation's best year, 1907. Allotted per ton of steel products made the earnings were \$7.95 per ton, thus falling below the previous minimum, \$8.65 in 1912, and thus being but 48 per cent of the highest average shown, that for 1902, \$16.59 per ton. Roughly speaking, the decrease in earnings per ton in twelve years has been approximately equal to the decrease in steel prices, but the Corporation's expenses, particularly in the average rate of wages and in the amount of taxes paid have greatly increased. These, apparently, have been offset by refinements in manufacture and by carrying the products, on the whole, to a greater degree of finish.

In 1902, with practically full employment of all the Corporation's manufacturing facilities, the output of steel products, weighed in the form in which sold, was 8,033,556 tons, while in 1914 the output of 9,014,512 tons is stated to have represented only about 62 per cent of the capacity, indicating an increase of about 75 per cent in capacity in twelve years, making the present capacity about 14,500,000 tons. During this time the bonded indebtedness, including bonds held in sinking funds, has been increased by \$345,000,000, while the preferred stock outstanding has been reduced by \$150,000,000, making a net increase of \$195,000,000 in the securities, an increase of 14 per cent. The actual value of plant facilities, per ton of finished steel capacity, has been very greatly increased, partly through refinements in manufacturing, for the production of the same material, and partly through the addition of finishing departments to carry steel to a higher degree of finish.

The Corporation's output of by-product coke in 1914

was 4,081,122 net tons, or 36.5 per cent of its total coke output, the highest proportion in its history, and comparing with a proportion of 6.1 per cent in 1907, the first year for which by-product coke was reported. The tonnage of Bessemer steel ingots was by far the smallest in the Corporation's history, only 4,151,510 gross tons, the proportions of ingot production being 35 per cent Bessemer and 65 per cent open-hearth. In 1902 the proportions were 69 per cent Bessemer and 31 per cent open-hearth. The relative productive capacity, however, has not changed so greatly, as in 1902 both Bessemer and open-hearth facilities were fully employed, while in 1914 there was a larger percentage of idleness in Bessemer than in open-hearth departments. It is entirely pertinent to observe, however, that in 1902, with full employment of the facilities, the open-hearth ingot production was 2,984,708 tons, while in 1914, with light employment, the production was 7,674,966 tons. The Corporation's maximum production of open-hearth ingots was 10,524,552 tons, in 1913.

While the total output of merchant steel was 12 per cent greater in 1914 than in 1902, the production of rails was 49 per cent less; tubing and pipe increased 23 per cent; sheets and tin plates increased 52 per cent, and there was a large increase in sundry products.

High-Grade Ore

There is no more spectacular incident in mining than the discovery of high-grade ore. It commands public attention, stimulates activity in prospecting and leasing, and brings visions of sudden wealth to the stockholders. There is a more sober side to the matter, however, that becomes painfully apparent when such ore is marketed. What is its true value and how shall it be determined? And when the value is ascertained, how shall the precious stuff be treated with minimum loss? The sampling and estimation of the value of high-grade ore is not a simple matter. Discrepancies rapidly mount into the thousands of dollars. Buyer and seller are far apart in their estimates, each sure that he is correct. The difference is so great that the common ground of agreement seems hopelessly unattainable. Both sides "play safe," knowing full well the chances of loss in the transaction.

The recent discovery of unusually rich ore in the Cresson mine in the Cripple Creek district was properly a cause of more than local excitement; but it is safe to say that before it was marketed it was the cause of considerable worry. It was originally sampled at a local sampling works and consigned to a Denver smelter where it was again sampled. The results of the two samplings were widely at variance, the reported difference of opinion representing about \$40,000 on the shipment. A resample was made at the smelter, and although the shipper's control sample checked closely enough with that of the smelter to have brought about a settlement, there was still the wide discrepancy with the original sampling. Buyer and seller could not agree and the ore was removed elsewhere for sale and treatment. There are some compensations in the steady production and treatment of ore of medium grade.

Readers' Views and Comments

The Radium Situation

To the Editor of Metallurgical & Chemical Engineering:

SIR:—In your March number Mr. Warren F. Bleecker makes a very remarkable statement which should not be permitted to go unchallenged by the chemists of this country. "There were," he says, "in this country no men who could determine radium quantitatively with any degree of accuracy," referring to the time when the Standard Chemical Company first entered the radium field. By those who have followed the development of radium from the beginning, who recall that practically all our knowledge of the quantitative relations of radium and radioactivity is based upon the work of Rutherford and Soddy at Montreal, who are familiar with the exact work of Boltwood at New Haven and of McCoy at Chicago, this statement will be taken for what it is worth, but it will no doubt afford comfort and solace to those curious individuals who take pleasure in depreciating what is nearest them.

With the substance, however, of Mr. Bleecker's paper I most heartily agree. If the Federal government goes into the radium business on the plea of monopoly, why not into the nickel business, and the manganese business, and the bread business, and every other business? Surely the interference of governmental agencies in private affairs has gone far enough for an English-speaking country.

STEWART J. LLOYD.

University of Alabama,
University, Ala.

* * *

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I thank Professor Lloyd for calling attention to the statement made by me relative to the accurate quantitative determination of radium. This statement is in error and I am pleased to correct it at this time.

A further explanation of the situation to which I referred is as follows:

During the time mentioned, which was in the years of 1910 and 1911, the founders of the Standard Chemical Company endeavored to obtain, in this country, the services of men of standing and authority, to measure and investigate radium in carnotite ores; and to one or more laboratories at least, samples of carnotite ore were sent for measurement and for advice as to possible extraction processes.

When it is realized that in the working out of a commercial process, the number of radium determinations upon the raw ores, intermediate and final products is very large and that there is a great variation in the kind of samples necessary for controlling the work, one may easily imagine that this work could not be well done within the limits of a university laboratory however skilled the operator might be in making a research in which he is not limited as to time.

We were taught in the early days that it was usually necessary, in making a determination of radium, to allow the samples to stand until the emanation had reached its equilibrium value, which is four weeks. In the control of a metallurgical process it is easily seen that this is out of the question.

While I am very glad to correct the statement, which, taken literally, is obviously incorrect and unjust, I wish again to call attention to the difference in the point of view between those who are doing academic work and those who are engaged in applying data and conclusions so obtained in a commercial way.

Industrial concerns must always look to the great men

of our universities to supply not only information about new things, but also to train a fair proportion of their students as far as possible in technique, so that when called upon, as they surely will be, to meet a demand for men to apply these things, it can be met safely and without embarrassment.

I had this situation in mind without realizing that a general statement relative to our peculiar relations to the measurement of radium, might cast reflection upon those who were in the work and upon whose researches we now base much of our knowledge about radium, as has justly been stated by Mr. Lloyd.

While Mr. Lloyd does not necessarily imply that we are of "those curious individuals who take pleasure in depreciating what is nearest them," it is but fair to say that it was not until July, 1912, that we were able to obtain the services of any one who was willing to come to our laboratory who had at the same time the ability to turn out results satisfactory for commercial work.

Further than this, we had previously had a gentleman with us who, without casting reflection upon the institution from which he was recommended, was unable to meet the requirements of his position. The only time I was able to get a positive statement from him as to the quantity of radium in any ore or product was just before his departure. Then he specifically told me that a resulting tailings product contained more radium than the ore from which it came, illustrating that his sense of humor was inversely in proportion to his ability to measure radium.

Standard Chemical Co.,
Canonsburg, Pa.

WARREN F. BLEECKER.

Carbon Bricks for Plant Furnaces

To the Editor of Metallurgical & Chemical Engineering:

SIR:—Permit me to ask the readers of your journal if carbon bricks have been used as lining for common pig-iron blast furnaces, and if so, with what result?

It seems that such bricks of a good quality ought to serve the purpose rather well, as far as the bottom is concerned, judging from the results obtained in electric furnaces for similar purpose, where they have proved very satisfactory.

The material is cheap in comparison with some other refractories, and the wear and tear far less than what one should anticipate.

JOH. HÄRDEN.

Guldsmidshyttan,
Sweden.

Comparisons of Electric Resistivities at High Temperatures

To the Editor Metallurgical and Chemical Engineering:

Sir:—In my article on the above subject in your January issue, Charts 1 and 2, page 24, there is an error in the curve for platinum. It is only in the extrapolated part, and as no values exist, the error is not important, but the figure nevertheless should be corrected.

Platinum melts at 1755 deg. C., and the figure for that metal should, therefore, rise abruptly and vertically at that temperature. No determinations, to my knowledge, have yet been made of the increase in resistivity of platinum at its melting point, nor even to show that it does increase; but presuming that it does, and assuming that, like most metals, the resistivity approximately doubles when the metal melts, the curve for platinum in Charts 1 and 2 should have been drawn accordingly. As this curve is merely extrapolated for

quite a wide range below its melting point, this correction is necessarily only very crude, though it seems to be the best information existing at present.

Philadelphia, Pa.

CARL HERING.

Chemical Engineering Versus Engineering Chemistry To the Editor of Metallurgical & Chemical Engineering:

Sir:—What's in a name? Perhaps but little; nevertheless, the writer, for one, has had some difficulty in seeing the difference between the two lines of activity implied in the title; and there are others at present who do not seem to realize that there is a difference. When I was a teacher of "pure" chemistry, the difference was not clear. When I had some of the hard, grueling experience of the University of Hard Knocks, I came to see what the difference is, and how tremendous it is.

Only recently I was asked, and by one of the prominent educators of the country, what is chemical engineering? To cut matters short, I told him that chemical engineering is industrial chemistry, which seemed to satisfy him; but, strictly speaking, the answer is by no means true. It is true that theory and practice in chemistry may merge into each other so that it is or may be hard to discriminate, at times; but in the large sense, chemical engineering ought to be more than engineering or industrial chemistry. But let us take an illustration.

The manufacture of sulphuric acid by the contact process, or rather by any one of them, can be worked out in the laboratory of pure chemistry. We may ascertain the substances involved in the special reactions used. We may test out the results by careful quantitative work. We may even go so far as to plan the design of commercial works for this process. We may be able to make some provisional and tentative estimates of costs and expenses. All this is good; it is essential; but it is only industrial or engineering chemistry.

The well-planned process becomes chemical engineering, only when it is carried over to the actual manufacturing conditions and results. Then there appear conditions which must be unknown to small dimensions and crude conditions of the experimental laboratory. When one enlarges apparatus from test-tube-and-beaker to small commercial size, there invariably appear new conditions and new troubles, unguessed and undreamed of at the earlier stage; and when one advances from small commercial size to true generous commercial dimensions, then other new and more vexing problems appear to be studied and solved on this large-scale plant. All this is so well known to the experienced engineer that it may seem not worth mentioning; but this common truism is not known, nor properly appreciated by the educators who are just waking up to the problems of establishing schools of real chemical engineering. I presume that it is something which can come only from hard and bitter experience—this realization of what engineering is, as distinct from the theory of what it ought to be, or might be. It seems to be what each one must learn for himself.

At what then shall the teacher of chemical engineering aim? It will be a safe theory to follow, to assume that the schools should try to give the student both the foundations, and also the immediate connections of these foundations with actual practice. I assume that the student has been given good and long training in the various branches of chemistry, together with the essentials of physics, mechanics, the "handy" acquaintance with mathematics, depending on his special aptitude in that much abused necessity, the basis of drafting, materials and this especially, a practical reading familiarity with French and German, and command of writing his ideas in commonsense English. But all this

is only the preparation for the actual struggle now to come, the mastery of the principles of chemical engineering, and the practice of the chief processes involved in their application. Now it is easy to enumerate some of the eternal chemical processes; they include solution, mixing, precipitating, filtering, drying, conveying, distillation, etc.

Let us take the old process of filtering for example. The student should be required to take down, inspect and reassemble any one of the good old types of filter-press. He should be given the same course with some of the newer types, such as the remarkable Sweetland filter-press, which has been described in the pages of *Metallurgical and Chemical Engineering*. He should be taught to look out for new and progressive attempts to solve the problem of continuous filtration, illustrated, for example, by such a machine as the "Filtros" continuous filter, described on page 125 of the February, 1915, issue of this journal; and he should do it by means of a specimen of the new machine large enough to show its commercial use.

In all this the student must inevitably run across the business questions of power, labor, wages, etc., and he must be shown how to incorporate all this in his estimate of the special suitability of the various types of filters for the special problems to be studied. And in deciding what is the best machine for the special material to be treated, there is no better rule than that of Mr. Edison, "If you want to find out a thing, try it."

And so on, with all the chief chemical processes—each must be studied with enough equipment to show what is being done, and what improvements are needed and possible.

But what of the fundamental chemical and mechanical principles involved in chemical engineering? What of the production; the transference; the use; the measurement of heat, electricity, power; what of all these? It goes without saying that they must be mastered, but would it not be well to have the student always master them in connection with the construction and use of some special machine or process? In this way the student will always have his attention focussed on the commercial use of his materials and methods.

But what of the questions to be faced in the title of this paper? What of the relations of engineering chemistry on the one hand, with chemical engineering on the other? I presume that for the schools of one kind it may be well to teach directly certain trades, such as dyeing, tanning, soap-making, sugar refining and the like. There is a call for young men so trained; and some of our most helpful schools, as the Pratt Institute, do such work, and do it well.

But for the higher type of graduate engineering, it may be well to query whether the best results will be reached by the special training in special trades. Here it would seem that the very thoroughness involved will show that the most and the best can be done by training, practical training, in both the processes and the principles involved and implied in the application of the laboratory to the factory. But this demands large equipment in power, buildings and machines, not to speak of the implied laboratory and shops accessory thereto.

And this brings us to our conclusion, namely, that the chasm between engineering chemistry and chemical engineering must be closed up as fast and as thoroughly as possible. Not that it can ever be entirely bridged over, but the gap can be lessened and, by dint of wise and persistent effort, we may be able to put and keep the young enthusiast in closer touch with the engineering idea: "Go as far as you can see; and then see how far you can go."

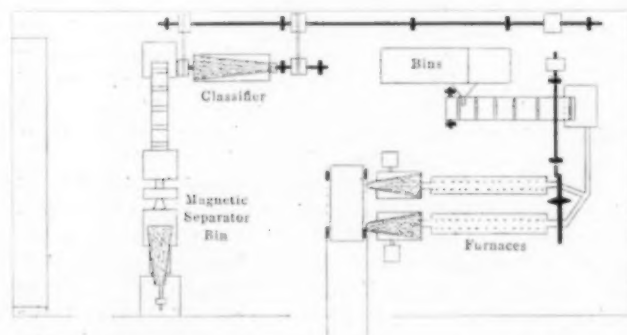
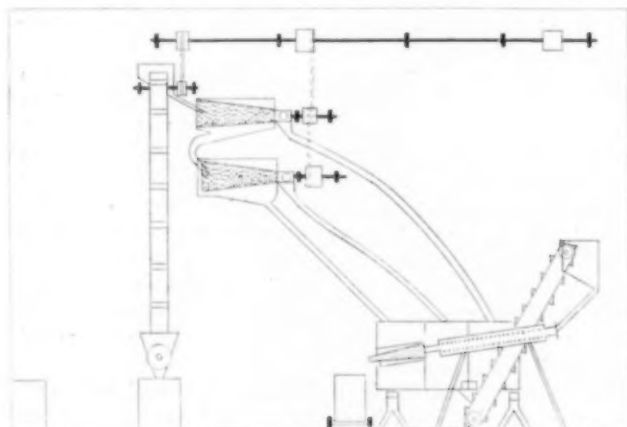
CHARLES S. PALMER.

Newtonville, Mass.

Separation of White Metal and Gunmetal Borings

To the Editor of Metallurgical & Chemical Engineering:

SIR:—In locomotive machine shops there is produced a large quantity of gunmetal borings mixed with white metal, which, in certain cases, is very difficult to deal with. So far as we are aware the only method used for effecting a separation is liquation on an iron plate or in a furnace. This process is only suitable for coarse borings and absolutely useless for the finer grade material. Owing to the rapid accumulation of fine borings in the New South Wales Railway workshops it was necessary to devise a scheme for the recovery of these two classes of metal and keep them in circulation. This metal cannot be smelted straight out and used generally for castings on account of the high antimony content—0.6%. It could, perhaps, be used for a few special castings, but for general rail-



ARRANGEMENT OF PLANT FOR THE SEPARATION OF WHITE METAL FROM GUNMETAL BORINGS

way purposes, a mixture of this kind would probably soon lead to serious trouble.

Under present conditions the borings taken from the machines are shaken on a $\frac{1}{4}$ -inch mesh sieve and the coarse white metal separated from the gunmetal by liquation on an iron plate. The removal of the white metal in the fine borings is the problem we were asked to solve.

After a few experiments it was decided to pass the small borings from bin to a magnetic separator, pick them up by revolving belt fitted with pockets, and convey them to a bin above classifiers. From this bin the borings gravitate to classifiers and are separated into three grades. From bins Nos. 1 and 2 containing the coarser material, the borings gravitate on to a short revolving belt fitted with pockets and are delivered into a bin above the furnaces and here gravitate to the furnaces. These furnaces are constructed of iron tubes, one fitting inside the other. The outer one being several inches larger in diameter than the

inner one, is supported by means of brackets to the floor and carries in the intervening space between the two tubes, a coil of iron pipe with suitable size perforations for heating the walls of the inner tube by gas. The inner tube is revolved and the hot borings and liquid white metal pass into revolving screens smaller in mesh than the last classifier, and the liquid white metal mixed with the borings allowed to escape through the screen into an outer vessel surrounding the screen, and which is heated by a gas coil. In this way the white metal does not cool, but collects at the bottom and can be run into moulds.

The clean borings pass along the screen into a hand truck on wheels, which can be taken to the foundry and the borings smelted and utilized for ordinary gun-metal castings.

The finest grade in No. 3 in., which is only a small percentage of the total, will probably have to be smelted and the bulk of the antimony got rid of by oxidation.

The sketch herewith shows the arrangement of the scheme suggested for the treatment of the above class of material at the railway workshops.

Bondi, Sydney,
New South Wales,
Australia.

R. H. WALTON,
GREGORY T. BAILEY.

Tube-Milling in All-Slime Cyanide Practice

To the Editor of Metallurgical & Chemical Engineering:

SIR:—I am much indebted to Mr. Haynes for putting in concrete form much that I would like to have said on closed-circuit tube-milling. As he shows, the cumulative load going to a tube-mill makes a preposterous proposition if the original load is more than the tube can grind. If it cannot fully grind the original 100 tons of battery pulp, it cannot grind 67 tons of return feed plus another 100 tons of new pulp.

It is contrary to all logic to overload any machine and then return the untreated part to the same machine. We went through that experience when the Wilfley and other concentrating tables came out. Every table was equipped with a return elevator for middlings. What became of those elevators? They promptly went to the scrap heap; and the solution of the middlings problem was found in separate treatment, regrinding and re-treating on separate tables. In cement factories we find large tube-mills used. Do they use "closed circuit" or "open circuit"? Has it not been fully determined in roll-crushing plants that small sizes must be eliminated and sent to other rolls, and that it is not economy to grind several sizes in one machine? We see in Mexico that even in crushing for the making of *tequila* the fresh material goes to the first set of rolls and the partly crushed stuff to a second set. In fact, is it customary in any mechanical work of this kind to return an unfinished product to be treated with fresh material?

We then come back to the possible claim that the partly ground sand from a tube-mill is so easy to finish that on its return to the tube it is properly ground during the second cycle. If so, it shows that it would be better to work tube-mills in series, as quoted by Mr. Haynes in referring to the Liberty Bell mill. Sufficient tube-mill capacity has to be provided to do the required work, and I believe it will require more tube-mills to do the grinding in closed circuit than in open circuit in series, with an intermediate classifier. Indeed, I think that the work can be done with tubes in parallel, with open circuit, feeding a pulp of low-moisture content. I think that high-discharge mills necessitated high moisture; high moisture made poor grinding; poor grinding occasioned the return of unground pulp, and the return was wrongly made to the same tubes instead of additional ones. A tube-mill should have all the neces-

sary elements wherewith to grind in one cycle to the required degree of fineness. The varying positions of the ore particles with reference to the diameter of the mill, and the many sizes of pebbles in the charge, furnish a multitude of grinding conditions to fulfill all requirements. A tube-mill will grind new feed plus return pulp if the conditions be right; but it can grind only so much ore and an overload results in poor work.

A point that I have observed in tube-milling is that on feeding coarse mine rock for pebbles, the angular projections or corners are broken off quickly and accumulate in excess of the quantity required to fill the interstitial spaces. They then discharge through the screen plate at the tail of the mill and if fed back by hand they continue to be discharged, since they form a cumulative load that the tube cannot grind. They must be taken up to the batteries in order to successfully dispose of them. When flint pebbles are used for grinders this condition does not exist, as the pebbles wear only in proportion to the grinding done. In fact, if a tube is started with large pebbles only, it will do very poor work until a sufficient number of small pebbles form to fill the voids.

Although not wholly pertinent to the discussion, I want to comment on the custom we have of referring to fine grinding in terms of "per cent through 200-mesh." It is an arbitrary and indefinite term, particularly because it gives no clue to the degree of fineness to which the whole pulp is ground. It tells nothing about the fraction that is not ground through 200-mesh, and very often it is this fraction that influences final extraction. If this fraction passes 150-mesh and the extraction is satisfactory, it would be better to use the term 150-mesh for the whole. If the fraction passes 150-mesh and the extraction is not satisfactory and can be made so only by grinding to 175 or 200-mesh, then that term should be used. In short, the practice of referring to "per cent through 200" leaves us in the dark regarding the coarser portion which, while it is not mentioned, may be the critical feature of the grinding.

I recall one plant in which we were treating 1000 or more tons daily. The final pulp going to the treatment vats averaged from 67 per cent to 70 per cent minus 200-mesh. The plus 200 caused poor extraction, occasioned high cost and stuck up the vats. Without changing the crushing and grinding equipment, we modified the classifiers and fed 30 per cent moisture pulp to the tubes. Classification was greatly improved, extraction increased, costs came down and no further trouble was experienced with the ore in the vats. Eighty per cent of the ore passed 200-mesh, and we still spoke of our grinding in terms of that figure. Would it not have been more significant if we had expressed our former grinding as 120-mesh and the latter as 175-mesh, rather than 68 per cent minus 200 and 80 per cent minus 200, respectively.

Guadalajara, Mexico.

W. J. PENTLAND.

Grinding Ore for Cyanidation: A Suggested Modification for All-Slime Practice

To the Editor of Metallurgical & Chemical Engineering:

SIRS—I have been gratified to see that my contributions to the discussion of cyanide practice have evoked some comments, as shown by the articles of Mr. Pettis and Mr. Haynes in your January number. I am sure that a good deal has been overlooked in general practice by the failure to treat distinct parts of the ore according to their particular conditions or needs. It was not my intention to suggest or formulate a procedure applicable to all ores, but to call attention to the feature of giving particular treatment to different parts of the same ore.

The subject offers a large field for discussion. We have first the probability that there has been too pronounced a tendency to rush to all-sliming, overlooking the possibility that it might be advisable to leach all the sands, coarse and fine, or that the fine sand might better have agitation with or apart from the slime, and only the coarse sand leached.

The matter of removing concentratable material, either because of its injurious effect in consuming cyanide, or because it requires more elaborate treatment, has usually been duly investigated; but further investigation into the subject of segregating other parts of the ore has generally been overlooked, although the nature of the problem is the same.

My attention has been called to this subject by the experience of many mining companies in Mexico. Most of them began operations with ordinary battery crushing, concentration, slime agitation and sand leaching. The concentrates were shipped to smelters or cyanided separately. All sliming then came into vogue; slimey and sandy gangue matter yielded to agitation, but the old question regarding concentrates still survived. Most of the operators came to the conclusion that it was more economical to abandon concentration and to slime everything. This was a decided move in opposition to the idea of special treatment for different parts of the ore; but as any gain in ultimate economy is the final deciding factor, the change was to that extent an advance in method of treatment.

Many of these plants are now agitating for 48 hours, using 6, 7 or 8-lb. cyanide solution. Such treatment probably is called for by the concentrates and coarse sands, even though quite finely ground, and so all the ore receives the maximum treatment. Nevertheless, I believe that an advantage might be found in making a separation at the classifier, providing separate treatment for the slime and for the sand with accompanying concentrate, perhaps combining the two portions at some later stage after the sand and concentrate had received special treatment. Continuous treatment methods make many things possible that were impossible with intermittent methods. It would be quite a different matter to provide stock or storage tanks in which to accumulate several different kinds of pulp for subsequent treatment by an intermittent process.

Arrangement of plant for agitation of two products is not so complicated as might be thought. Suppose that slime and sand each comprise 50 per cent of an ore and that four agitators are in use. The slime from the classifier could flow direct to a thickener and thence to the last two agitators. The sand discharged from the tube-mill could flow through the first two agitators and then to the thickener, from which the combined pulp could then pass to the last two agitators. Thus the sandy portion would receive double the agitation of the slime. This scheme does not contemplate closed-circuit tube-milling; but for those operators who prefer that method a primary and secondary classifier would be necessary in order that the tube-mill discharge could be classified without mixing with fresh battery product.

Under this scheme, standardizing of agitating solution could be made where it would do the most good.

If it were desirable to separate coarse sand for leaching, that could be done by classifying the tube-mill discharge. If it happened that the slime were the part requiring more extended treatment, the system could be arranged accordingly.

It would, indeed, be strange if the cyanide process should prove to be the only method of ore-treatment wherein it were found desirable to treat the whole ore as one product rather than as two or more. In smelting we go to extremes in the mechanical handling of ores; smelting some just as they come from the mines; treat-

ing others by roasting, sintering, briquetting or other appropriate processes; recovering and re-treating flue-dust and other by-products. In concentration we classify and size without end, and regrind and reconcentrate middlings. And yet cyanide operators sometimes try to do the whole thing in one operation, on the assumption that the simpler the process the more economical. Is not too much being expected of that simple solvent, cyanide?

All-sliming of concentratable ores and agitation of the total ore as one product, undoubtedly gave better economical results than did concentration, slime agitation and sand leachings, or the plants would not have been changed. But did not the operators go one step too far when they decided to agitate all the products together, making the conditions of treatment for the most refractory part be guide for the whole ore?

Guadalajara, Mexico.

W. J. PENTLAND.

The Danger of Throwing Inventions Open to the Public

To the Editor of Metallurgical & Chemical Engineering:

Sir:—The public press now teems with statements regarding the new inventions and developments of Dr. Rittman and their importance. The announcement is made that these discoveries, after patenting, would be thrown open to all. This, if true, does not offer much hope that they will be adopted and developed for the reason that the value of a patent usually or at least often lies, not in establishing a monopoly in the patent itself, but in the incidental protection it affords to those who do the missionary work, that is the effort and money expended in developing it and making a market for the product.

It has already been stated that about the surest way to prevent the development of a new invention or process is to throw it open to anyone who chooses to practice it. If any competitor may adopt and use the means and appropriate the knowledge gained in developing an invention and marketing its product one seldom feels disposed to embark in the work, but if he does, then he must generally conduct it as a secret process if any suitable profit is to be expected.

It is a long way and one not often traveled from the conception of a truly original invention or even from the issuing of a patent therefor, to a profit from its use. If it is what might be called a secondary invention representing a minor advance in some article or method already commercially established the case is of course different and the invention may be in full use before the patent is applied for.

What the public wants is for meritorious inventions or improvements to be made and then put to use. An invention to be adopted must offer a substantial increase in value or service over what has occupied the field it aims to work in, and if the inventor gets for himself even a small fraction of the increase or saving which results, he is fortunate. His share will never be great enough to deter anyone from working the improvement.

If Dr. Rittman's inventions work in with the established methods of parties doing business in the allied lines, they may, of course, be taken up by such parties, but if they are of revolutionary character then the encouragement for their development and working, without protection, becomes small. Old business is naturally conservative, and a new invention which threatens if adopted to "scrap" existing plants, wholly or in large part, will usually be unwelcome until possibly its acceptance is forced by the march of events. The working up of the revolutionary invention must then be undertaken, if at all, by newcomers in the business with the chances against success.

Dr. Rittman might therefore promote the general good better and induce the introduction of his inventions quicker if he remains in position to afford pioneers in their development such protection that those who lie low waiting for others to show the way would not be able to come in later and reap where they had not sown. The only way for him to do this is to retain the patent rights for himself, or his assigns.

In this connection it might be said that if some legal way existed by which a business enterprise which develops and produces new goods could be protected from unfair imitation and competition when patent protection cannot be obtained, it would seemingly inure to the advancement of the arts and the public welfare. A new thing is not necessarily patentable.

Plainfield, N. J.

HENRY D. HIBBARD.

The Western Metallurgical Field Smelter-Smoke Litigation in California

The vagaries of smelter-smoke litigation are well illustrated in some of the cases that have hampered the smelting industry of California. In Shasta county, in the northern part of the state, the farmers succeeded in closing all the smelters except that of the Mammoth Copper Mining Co., which continued in operation under a system of neutralization of acid gases, and bag-house collection of dust and fume. By the method employed, which was described in METALLURGICAL AND CHEMICAL ENGINEERING for December, 1914, the company was enabled to keep within the terms of the court decree relating to the composition of discharged smoke. Farther south, in the vicinity of San Francisco, the Selby Smelting & Lead Co. finally had its troubles satisfactorily adjusted through a commission, which found that the terms of the court decree were being substantially complied with. During the troublous times for these companies, however, the Penn Mining Co., operating a copper smelter at Campo Seco, in Calaveras county, was left undisturbed. Apparently its time has now come, for no fewer than 35 suits are reported to have been filed against it by the farmers in the immediate vicinity.

Some time since California had a state commission, appointed by the governor, to investigate the smelter-smoke situation. In their report, made about the end of 1914, they found that conditions around the Mammoth smelter were unfavorable, despite previous judgment to the contrary; but no strikingly unfavorable report was made as to Campo Seco and the Penn company. Hence, the latest developments are strangely unaccountable. The federal court has within less than a month again denied an injunction against the Mammoth company, in which the farmers alleged a violation of the decree; and since the first of this year 35 suits have been filed against the Penn company. Evidently the state commission, the federal court and the farmers are not in accord. It is rumored that covetous lawyers have stirred up the trouble among the hitherto satisfied farmers around Campo Seco, and have piled up suits for damage aggregating over \$300,000, expecting to make their fortune through contingent fees. The scheme is old and moth-eaten. It worked in the early days of smelter-smoke litigation, when the smelters compromised and paid for real and alleged damage until the condition became unbearable; but it can scarcely be taken seriously in this day of scientific investigation of such damage. Such suits cost tremendous sums of money, requiring the services of many experts; and it is safe to say that smelters probably are much better posted as to genuine damage caused by smelter smoke than are a

group of farmers misled by lawyers. When the latter learn what it costs to secure the necessary testimony to support their cases, interest in the contingent fees is likely to wane.

Reduced Shipments from Cobalt in 1914

According to figures prepared by Mr. A. A. Cole, mining engineer for the Temiskaming and Northern Ontario Railway Commission, the bullion shipments from Cobalt, Ontario, during 1914 amounted to 9,624,629 ounces of silver, valued at \$5,254,097. Compared with the shipments for 1913, there was a decrease last year of about 200,000 ounces, due mainly to disturbances in the mining industry caused by the war. The decrease in value of the 1914 output as compared with that of 1913 was about \$600,000, due to the low price of silver prevailing during the last year. The Nipissing company contributed nearly 75 per cent of the total bullion output, amounting to over 600,000 ounces; but this was lower than for 1913 by nearly 230,000 ounces. The Buffalo company was second, with a total of over 900,000 ounces. This also was lower than for the preceding year, as the company operated only for the first seven months of the year. On the other hand, the Dominion Reduction and O'Brien companies showed substantial increases over 1913, as did also some other companies. Kerr Lake showed the greatest increase, producing over 400,000 ounces in 1914, as against 50,000 in 1913. The following list gives the shipment and value of bullion as compiled for 1914 by Mr. Cole:

Company	Ounces	Value
Bailey	1,353.95	\$785.27
Beaver	9,849.00	5,004.09
Buffalo	912,250.00	509,013.35
Casey Cobalt	2,566.64	1,343.72
City of Cobalt	27,341.64	15,523.75
Cobalt Comet	1,597.54	923.65
Cobalt Townsite	36,538.86	19,580.17
Crown Reserve	626,374.00	343,822.52
Dominion Reduction	726,397.85	405,885.50
Foster Cobalt	2,157.13	1,017.62
Hargraves	794.00	414.81
Kerr Lake	407,238.53	183,970.15
La Rose	55,365.48	29,066.87
McKinley-Darragh	17,470.00	10,016.55
Nipissing & Customs	6,299,677.75	3,469,526.13
O'Brien	452,822.00	243,933.91
Penn-Canadian	16,454.94	8,839.69
Temiskaming	6,163.70	3,553.20
Toowasite-City	17,640.35	8,465.83
Trethewey	4,576.04	2,409.86
	9,624,629.40	\$5,254,096.64

In the latter part of February the Nipissing company made one of the largest shipments of bullion in its history. The consignment comprised 320 bars containing 376,709 fine ounces of silver, valued at \$183,645. The shipment followed the period of annual clean-up at the mills, and brings the total bullion shipments for 1915 past 1,000,000 ounces. Ore shipments from the Cobalt district, however, were low during February, amounting to only 995 tons of ore and concentrates. This is the lowest monthly shipment in seven years, and is also the first in which the monthly shipment has fallen below the 1000-ton mark. The decrease is ascribed to shortage of power during the month.

Progress with the cyanide plant annex to the concentrating mill of the Cobalt Reduction Company is being rapidly made; the building has been completed and the cyanide machinery is being installed.

Anaconda and Butte-Duluth

It is reported that the Anaconda Copper Mining Co. has failed to exercise its option on the mining and metallurgical property of the Butte-Duluth Mining Co. The failure to exercise the option seems not to have interfered with further negotiations with new interests, and it is announced that a new 60-day option has been given another concern. Anaconda is re-

ported to have found the mine and leaching plant satisfactory, but disagreed with Butte-Duluth on the terms of sale.

Federal Mining Experiment Stations

The bill to establish ten mining experiment stations in the mining states, for the purpose of making investigations in the interest of better metallurgy, passed both houses of Congress and has been signed by the President. As no appropriation was provided in the bill, its terms cannot be put into effect at this time.

Company Reports

The report of the Arizona Copper Co. for the year ended September 30, 1914, shows a production of 38,942,455 lb. of copper, compared with 34,230,000 lb. for the previous year. Due to the lower price received for copper in 1914, the profit fell off over \$700,000, a considerable proportion of which is directly attributed to the outbreak of the war. Drastic reduction in output was made directly following declaration of war, but in view of the recent improvement in demand, the production has been increased since January 1. Dividends for the year amounted to about \$645,000. The sulphide concentrating department handled 932,945 tons of concentrating ore. The average ratio of concentration was 8.42:1. No. 6 concentrator was enlarged during the year and now has a capacity of about 3000 tons in 24 hours, but is not now running full time. The oxide concentrator and leaching plant treated 87,875 tons of ore, producing 5414 tons of concentrate, which was sent to the smelter. The leaching plant handled 72,649 tons of tailing.

The sulphuric acid plant supplied the leaching plant with 2937 tons of acid. Including ore treated at the old smelter during the first quarter, there was smelted 182,873 tons of ore and concentrate. The average yield of copper from this material was 10.65 per cent. The new smelting plant is reported to be working satisfactorily.

Butte & Superior Copper Company's report for the fourth quarter of 1914 shows the following operating data:

	Fourth Quarter	Third Quarter
Dry tons of ore milled	33,520	100,600
Average zinc content (per cent)	19.4538	18.582
Average silver content (oz. per ton)	8.9286	8.6359
Zinc concentrates produced (pounds)	20,464,000	60,974,968
Average zinc in concentrates (per cent)	53.947	54.32
Total zinc in concentrates (pounds)	11,039,557	33,121,312
Average silver in zinc concentrates (oz. per ton)	23.54	24.15
Mill recovery (per cent)	84.65	89.14
Mining cost per ton	\$3.285	\$3.201
Milling cost per ton	\$2.466	\$2.049
Total cost per ton, mining and milling	\$5.754	\$5.25

The low tonnage and production for the fourth quarter were due to closing the mill from October 17 to December 17. During this period extensive repairs were made and considerable remodeling done in the mill. Seven new cells were added to the flotation plant. The financial statement shows profit of \$130,537.

The Trethewey Silver Cobalt Mines, Ltd., produced during the calendar year 1914 a total of 527,097 oz. of silver, valued at \$251,843, as compared with the 1913 production of 619,429 oz., valued at \$333,611. Ore reserve is estimated as equivalent to one year's production. The average price received for silver in 1914 was 6.08 cents lower than for 1913. The mill cost was \$1.31 per ton, being 15 cents lower than for 1913. Shipments comprised 298 tons of concentrates averaging 1577.7 oz. silver per ton and 314 tons averaging 217.78 oz.

The Crown-Reserve Mining Co., Ltd., shows in its annual report for 1914 a production of 1,425,320 oz.

silver of a gross value of \$740,092. On account of the low price of silver and the war the receipts were probably \$100,000 lower than the same quantity of bullion would have produced in 1913. The milling record shows the treatment of 31,347 tons of ore, from which an average of 15 oz. per ton was returned. The total cost per ton was \$4.16. The average value of high-grade shipping ore was \$3,474. The cost of producing silver per ounce was 28.95 cents and the profit 22.97 cents. Dividends paid amounted to \$424,515.

The Porcupine-Crown Mines, Ltd., which is controlled by the Crown-Reserve company, shows a production of gold during 1914 valued at \$691,394 from 40,857 tons of ore of an average value of \$17.65 per ton. Referring to mill operations, the report states: "The continuous decantation process has not only been justified but has proved remarkably adapted to the ores of the Porcupine district and, with one exception, has been adopted by all the important mines in the district. The average extraction of the mill for the year was 97.26 per cent." The cost of mill operation is given as \$1.31 per ton. The estimated value of ore reserves is \$1,500,000. Dividends paid amounted to 12 per cent, or \$240,000.

The Non-Ferrous Metal Market

The general state of the non-ferrous metal market during March was one of confusion and uncertainty. Spelter continued its phenomenal rise to a point of collapse, but copper, lead and tin were firmer. The price of tin advanced decidedly, owing to scarcity of foreign supply.

Copper.—A good demand has existed, especially among domestic brass manufacturers, and the market is considered in a fairly strong position. During the early part of the month the price rose to 14.75 cents per pound, New York, with the prospect that it might go higher.

Lead.—Although domestic demand has continued rather light, foreign consumption is rather heavy and large shipments have been made abroad. The A. S. & R. Co. raised its price to 3.90 cents on March 1 and to 3.95 cents on March 5. The latest St. Louis quotations were $3.87\frac{1}{2}$ @ $3.92\frac{1}{2}$.

Tin.—Prices varied widely at the beginning of the month, rising as high as 48 cents. Domestic demand was slack and the advance in price was ascribed to anticipation of shortage of supply due to disturbance in the shipping situation. Following the rise, prices fell to about 45 cents, New York.

Spelter.—The spectacular advance in this market apparently culminated early in March, and although prices have not yet become settled they are on the decline. Metal for prompt delivery was scarce and brought fancy prices. Metal for June delivery was offered at 8 cents. The nominal New York quotation last available was about 7.75@8 cents; St. Louis, 7.60@7.75.

Other Metals.—Quotations for aluminum continue about 19@19 $\frac{1}{4}$ cents per pound, New York. A shortage in antimony again raised prices, different brands bringing from 21 to 27 cents per pound. Quicksilver also is up, \$65 being paid for flasks of 75 lb. at New York and \$60 to \$63 at San Francisco.

The New York Section of the American Institute of Mining Engineers will hold its next meeting on Wednesday, April 7, at the Machinery Club, 50 Church Street. Dinner will be taken at 6.30 and afterwards a discussion will be held on the economic side of safety and sanitation as applied to the mining and metallurgical industry.

The Iron and Steel Market

At the close of March the steel mills were operating at an average rate of fully 65 per cent of their ingot capacity, though naturally at a somewhat lower rate measured in terms of finishing capacity, as finishing capacity always exceeds steel-making capacity. The average rate in March was close to 65 per cent, against about 55 per cent in February, 45 per cent in January and 35 per cent in December. The improvement in trade opinion of the prospects, what is commonly denominated in market reports the "sentiment," began about the first week in November. The improvement in buying began in December, while the increase in production began about January 1. The improvement has been continuous. In March the increase in orders placed and in the rate of production was relatively slight, while the improvement in "sentiment" was decidedly marked. This decided improvement in the trade's hopes for its future was due chiefly to recognition of the fact that when a steel-trade improvement has lasted over a period of about four months it is entitled to a great measure of respect. The little spurts to which the trade has grown accustomed in recent years have been matters of a couple of months.

The alignment of demand for steel products has been quite abnormal. It is a remarkable thing to see the steel industry operating at practically two-thirds of its capacity when scarcely any railroad material is being made and when there is very little structural work in progress. In certain branches of the finished steel trade there has been almost full employment. The tin plate mills have operated at about 85 per cent of capacity in the past three months, substantially as heavy a rate as has ever been seen in a first quarter. The wire mills, with a very fair domestic demand and with an abnormally large export demand, have operated almost at capacity in February and March. The pipe mills have had nearly a full demand for standard pipe, while demand for line pipe has been only fair, and demand for boiler tubes and oil country goods has been extremely light. Less than 10 per cent of the total steel produced in March was for eventual railroad consumption, whereas the average of the past few years has been 15 to 20 per cent and in earlier years the proportion of railroad steel was still larger.

A detailed scrutiny of the steel market indicates rather plainly that there is no prospect of any decrease in demand from the rate of the past month, while there may easily be a slight increase merely from seasonal conditions. For any decided improvement over present conditions one thing is absolutely necessary, and that is a loosening of funds for permanent investment in railroad extensions and betterments and in bridges, buildings and manufacturing extensions of various sorts. The demand thus far experienced, apart from the export demand and the demand for shipbuilding material, has been confined almost exclusively to materials for common everyday consumption for wire and tin plate, for instance, as contrasted with rails, steel car material and structural shapes. The latest thought in the steel trade, which is strengthening the favorable views entertained for the future, is that there may be within a few months a loosening in investment funds through anticipation of an early termination of the European conflict.

Pig Iron

One of those movements for which the Buffalo pig-iron market is becoming noted occurred late in March, a total of perhaps 150,000 tons of Buffalo iron being sold for second quarter and later delivery, at an average of about \$11.75, f.o.b. Buffalo furnace. Apparently,

however, the movement was not due so much to a change in fundamental industrial conditions or to the buyers taking the initiative, but rather to the sellers dropping their prices and indicating that it was necessary for buyers to act promptly. After the Buffalo movement of last November, at about \$12, the furnaces advanced prices about \$1 a ton and have thus had room lately for making reductions. Other markets which had fair sales at that time did not advance and thus there are no facilities for arousing the interest of buyers in such markets. Apart from the Buffalo movement the pig-iron market continues dull and colorless—disappointing indeed since a large volume of contracts should expire April 1 while the evidences are that the tonnages have not been taken out as rapidly as the contracts contemplated. The market is quotable as follows: No. 2 foundry: Delivered Philadelphia, \$14; f.o.b. furnace, Buffalo, \$11.75 to \$12; delivered Cleveland, \$13.25; f.o.b. furnace, Chicago, \$13; f.o.b. Birmingham, \$9.25 to \$9.50; f.o.b. valley furnaces, 95 cents higher, delivered Pittsburgh: Bessemer, \$13.60; basic, \$12.50; No. 2 foundry, \$12.75 to \$13.25; malleable, \$12.75; gray forge, \$12.50 to \$12.75.

Steel

After a period of extreme inactivity some inquiry for billets and sheet bars developed late in March, for second quarter, and slightly higher prices were quoted than had been nominally in vogue for prompt shipment, about \$18.50 for billets and \$19 for sheet bars, f.o.b. maker's mill, Youngstown. There is practically no market being made in Pittsburgh, and the delivered Pittsburgh price is about a dollar a ton above the Youngstown basis. Deliveries on contracts were much heavier in March than in February. Rods are \$25 to \$26, Pittsburgh.

Finished Steel

The 1.10c. price for bars, plates and shapes disappeared March 1 according to program, leaving the market at 1.15c. for March and 1.20c. for second quarter, there being, of course, some exceptions when large lots for specific jobs were involved. The beginning of April, it is now hoped, will see a disappearance of the 1.15c. quotation. Sales of galvanized sheets at the mill price of 3.40c. have been extremely light. For one thing, many jobbers had contracts at much lower prices, made before the phenomenal advance in spelter, and became competitors of the mills, while for another thing consumers are quite averse to paying such high prices for galvanized sheets and if spelter does not decline sufficiently to permit galvanized sheets being sold at prices somewhat in harmony with those of the past the consumption will be materially reduced.

Current quotations are as follows for ordinary deliveries, quotations being f.o.b. Pittsburgh unless otherwise noted:

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.15c. to 1.20c.

Shapes, 1.15c. to 1.20c.

Steel bars and bands, 1.15c. to 1.20c., base; hoops, 1.25c. to 1.30c., base.

Refined iron bars, 1.15c., Pittsburgh; common iron bars, 1.12½c., Philadelphia; 1.12½c., Chicago.

Sheets, blue annealed, 10-gage, 1.30c.; black, 28-gage, 1.80c. to 1.90c.; galvanized, 28-gage, 3.40c.; painted corrugated, 28-gage, 2c.; galvanized corrugated, 28-gage, 3.45c.

Tin plate, \$3.20 to \$3.35 for 100-lb. cokes.

Steel pipe, 80 per cent off list.

Steel boiler tubes, 3½ to 4½ in., 74 per cent off list.

Standard railroad spikes, 1.35c., Pittsburgh; 1.45c., Chicago.

Cold-rolled shafting, 70 per cent off list of March 15, 1915, f.o.b. Pittsburgh.

Structural rivets, 1.35c.; boiler rivets, 1.45c.

Chain, ¾-in. proof coil, 3c.

Conditions in Mexico

The best impressions we can get regarding conditions in Mexico come from private correspondence that filters through on occasional mails. It is difficult, if not impossible, to draw general conclusions even from such sources, but they at least represent the daily happenings and are suggestive of the troublous times through which Mexico is passing. Commerce and industry must necessarily be at a standstill under the changing domination of conflicting parties, and mining is out of the question. The following excerpts from the correspondence of a managing engineer now at Guadalajara, Jalisco, covering a period of time from Jan. 10 to Feb. 25, show in a graphic manner the state of lawlessness that exists. They express the hope of the inhabitants in the "Villistas" and their fear of the "Carrancistas."

Jan. 10, 1915.

"We have had no violent experiences since the last attempt of the Villistas to enter the city at night, which was quickly repulsed. That was on the 30th of December, I think. For the last three days the Carrancistas have been getting ready to leave; some trains have left, but there are a great many of their troops still here. They have loaded enormous quantities of baggage and household furniture on the trains. We know nothing of the movements of opposing forces, but never lack for rumors of all kinds. This city is in a desperate state and the population in a state of dread all the time. Martial law in due form would be better than a disorganized state such as we have now.

"Some time back they ordered all rifles to be turned in. Foreigners were ordered to turn theirs in to their respective consulates. The authorities attempted to take possession of the arms in the consulates, and the Germans and French delivered theirs on a show of force. — sealed his consulate doors and went out of sight so as to avoid a discussion. The authorities attempted to force — to deliver up the British arms but he refused. They stood him up to shoot him and he dared them to go ahead. Then he sealed his doors and told them to break them down if they chose to do so. We admire his spirit, but if they go ahead and break his doors, they will also those of the American consulate. If bloodshed once starts over it, that will be the last of all of us, as they will then know that they have put their foot in it and might as well make a good job of it. They hung a railroad man last evening and shot another because the men did not wish to serve on the trains."

Jan. 31, 1915.

"Our latest has been an attempt by Julian to retrieve his lost fortunes and take this city from the Carrancistas. I guess he thinks that if Villa has to come over to take it again he will put some other *hombre* on the job as governor, seeing that Julian lost out after having been seated on the throne.

"Saturday, 30th, at 5.15 a. m., we heard one of the d— shootings that we have yet been treated to—and it has to be something out of the ordinary these days if it is to attract attention. They came into town by every road available, and if they had had any head they would have had the place, as every cut-throat thought his time had come. Some yell, that, "Viva Villa," to judge by its effects. But somehow advantages were not utilized, and in the end Julian and his took up their quarters on the outside again. Some excitement, though, for disinterested people, these daylight attacks. Makes it bad about the cooking, as the *criadas* do not come to work for a day or two.

"About noon a cannon got working against the packing house where it was supposed some of the outsiders had taken refuge. Do not know what damage they did to the packing house, but they killed old —, the moonshiner who lived at the defunct distillery near by. We know nothing of the outside world; mails, telegraphs and trains are dead."

Feb. 8, 1915.

"Today is another red letter day with all the excitement that goes with big doings. The Carrancistas are on the move again—another evacuation—and the grabbing of things belonging to other people makes us stay at home and keep the back gate shut securely."

"Last night troops were moving all night, and we knew that something was in the air. It is said that the Villistas have taken Colima.

"We have quite a time with the paper money. Dieguez would not permit any Villa money to circulate, so that his own stuff should have the preference. This morning Villa paper is already being received in general. Everybody wears a glad smile this morning, even though they are fearful of what might happen before this crowd leaves. Exchange has been around eight and nine for one lately, but little business done of course. I do not believe I would buy up much for speculation if I had lots of idle money.

"Unless relief comes to this country soon there is going to be some actual human suffering for the needs of ordinary daily life. If one could believe that the experience of the people would do them some good in making them realize the responsibilities of life and country, there might be some consolation in the reflection; but reasoning powers they have not nor ever will have, so it becomes a matter of cruelty to animals."

Feb. 11, 1915.

"No change of scene; just the same old terror existing. Yesterday I saw part of a fracas in which one of these high-binders found a petty excuse for using his gun, and shot a man at the Casino below the American Club. We heard two shots, saw the victim run and fall at the corner, get up and stagger around while the high-binder looked for a chance to aim his pistol again. Our friend — stepped in between, as did also —. Many others came running up, and they induced the victim to go to the palace where it was finally determined that he was not to blame. The governor was sorry, and the high-binder went away without being able to finish his story.

"Last night they shot two women on the street for being out after 8 p. m., and not being able to tell a good story quickly. Today they threatened some clerks because they declined to take some bad bills. I saw the soldiers go in after them. They said this afternoon that the clerks had been shot, but I could not confirm the story.

"This morning the brewery cashier declined to change a bad bill—said he had no change. Complaint was made and the soldiers went after him and made him open the safe, when it was found that he had lots of change. They fined the brewery a thousand pesos, and when payment was offered in their own money, they refused the bills as being bad money.

"Most of the high-binders have been living on their trains for the last several days, ready to move; but for some unknown reason they remain. How the people would like to see this bunch get out, and a set of real devils come in in their place, so that the city could have a little peace. I never thought that I could live in such an atmosphere as we have had here of late. What we go through every day would be the event of a life-time in the States. People are so thoroughly terrified that no one dares talk with anyone not an American or an Englishman. Our noble American Consul has been in hiding for three days; and today we see that a notice has been pasted on the door stating that affairs of our consulate have been turned over to the British Consul."

Feb. 13, 1915.

"Well, they put us on the map again today. Villa came in with a small bodyguard of cavalry, and the ovation he got from the city was something to be remembered. The American Consul came out of hiding this morning, and was around telling why he hid and left his *nationales* orphans. An old federal judge, Delgado, is said to be slated for governor. Poor Julian lost his job. Villa is supposed to have sent a lot of men after Dieguez, and will finish him now as he should have done in December. Our spirits have come up greatly since noon. Perhaps we shall be permitted to live a while longer."

Feb. 17, 1915.

"We have had several days of speculation as to what the new outfit would be able to do to the outs. Villa himself is at the front, and we imagine that they are doing some real fighting. Villa has an aeroplane with him. It left here yesterday morning and got part way to the front.

"We hear that Villa has declared the country cut in two parts, and that the line runs from below Manzanillo to below Tampico. That puts us in the north, for which we are thankful. All of us are now figuring on when we can do something. These folks are now busy cleaning up the town of traces of Carrancistas. I guess that they get away with a good many of them, and I hope they get the last of them and make good Indians of them.

"They say that Julian will have his job back after all, and I would rather he did, as we are better off if we have someone that we know personally. He has been expected

in town for a day or so, but his feet must have been sore from the brush run that he made, and so he has been slow getting back. Dieguez took away everything in the way of an engine that could be moved, and those that could not be moved he tried to ruin. He broke up the railway shops and raised Cain generally so they cannot rustle engines for traffic. If Dieguez ever gets back here, it's good-bye Guadalupe."

Feb. 25, 1915.

"I have your letters of Nov. 11, Jan. 11 and 25, all having come in a few days ago by the first train bringing mail for some time. Having ventured out toward our diggings, I was gone a few days and so have not written immediately. I got within speaking distance of the mines, that is, speaking over the telephone forty miles. That is doing fairly well, though, considering the circumstances.

"The Southern Pacific track from Orendain to La Quemada consists of two streaks of rust and a mushroom bed; at least the rotten wood that was formerly ties can serve now only for planting mushrooms. They have not had a new tie in over a year, and whenever they rustle a car of ties, some military train comes along and takes them for fuel. They have a locomotive, two cars, a conductor and engineer at La Quemada, but none of them can be moved as there is no oil for the engine, and the crew is looking for something to eat.

"We really know nothing of what is going on in the country. There has been heavy fighting down toward Colima, but what the result is we know not, and people are fearful that the old crowd may return some day. Our only satisfaction, and it may be an illusion, is that living is extraordinarily cheap for those of us that are on gold salaries. The poor devils that are on a peso basis are in a bad way. The natives also are in a bad way, as prices are frightfully high, and but little work to be had.

"Trains go out toward Irapuato frequently, and some come in, so mail is moving somewhat; but any day we may be cut off. If you get no mail from me in a long time, you may take it for granted that there has been a change of play and a new film on. If the Carrancistas get back into this place, our cake will be all dough."

Atlantic City Meeting of the American Electrochemical Society

The annual meeting of the American Electrochemical Society will be held in Atlantic City from Thursday to Saturday, April 22 to 24, 1915. The headquarters will be at the Hotel Chalfonte.

Sessions for the reading and discussion of papers will be held on Thursday afternoon and Friday morning and afternoon. On Thursday evening Professor William S. Franklin of Lehigh University will lecture on models of electromagnetic phenomena. On Friday evening an informal smoker will be held.

On Saturday morning a train will be taken to Philadelphia and sessions will be held in the morning and afternoon at the Harrison Chemical Laboratories of the University of Pennsylvania. Between the sessions lunch will be taken at Houston Hall. In the afternoon session a lecture will be delivered by Provost Edgar F. Smith of the University of Pennsylvania.

New Orleans Meeting of the American Chemical Society

The fiftieth meeting of the American Chemical Society will be held at New Orleans, La., from Wednesday, March 31, to Saturday, April 3, 1915. Headquarters are at the Hotel Grunewald.

The feature of the convention will be a general meeting on April, in which nineteen different papers will be presented in the contributions of the chemist to different industries. The opening address will be made by Dr. A. D. Little, of Boston, on the industrial resources and opportunities of the South, while in the evening Dr. Bernhard C. Hesse will speak on the chemists' contribution to the industrial development of the United States.

The Electrochemical Production of Organic Compounds

The New York Section of the American Electrochemical Society held the fourth regular meeting of the season at the Chemists' Club on the evening of Feb. 5. This was a joint meeting with the New York sections of the American Chemical Society and the Society of Chemical Industry. The evening was devoted to a symposium of papers on the electrochemical production of organic compounds.

Introductory Remarks

Dr. COLIN G. FINK, chairman of the New York Section of the American Electrochemical Society, introduced the subject by the following remarks:

"The subject of organic electrochemistry is a new one in America. If you will look over the membership list of the American Electrochemical Society you will find that most of the members are metallurgists and inorganic chemists. Another large percentage is composed of electrical and mining engineers. The organic chemists form a very small group.

"The subject of organic electrochemistry is a very important one, yet owing to an unfortunate tendency on the part of the organic chemist to shun physical chemistry and a like tendency on the part of the electrochemist to shun things organic, the field of organic electrochemistry has been badly neglected. However, it was not the electrochemist who chose the inorganic lines but rather the inorganic chemists and engineers were induced to adopt electrochemical methods—methods which at first often seemed very impractical but eventually superseded all others. It was only a few years ago when the making of steel in the electric furnace was ridiculed by almost every chemist and engineer.

"There are three distinct reasons for introducing the subject of organic electrochemistry at this time:

"(1) In consequence of the European war the coal-tar industry in this country has received a great impetus.

"(2) Our European contemporaries, notably Elbs and his co-workers, have demonstrated conclusively that a large number of organic compounds, can be better and easier produced by electrochemical means than by any other.

"(3) Many of the electrochemical processes for inorganic products have been standardized and the electrochemist is looking for new fields to invade."

The Commercial Aspects of Organic Electrochemistry

Mr. F. AUSTIN LIDBURY, manager of the Oldbury Electrochemical Company of Niagara Falls and president of the American Electrochemical Society, presented a paper on the commercial aspects of electrochemistry.

Mr. Lidbury drew attention to the fact that the present disturbed conditions, which have thrown this country upon its own resources to a large extent, had made clear the brilliant position of the country in regard to its electrochemical industries; while quite another adjective would have to be applied in reference to the organic chemical industries. The reason for this was to be found largely in the fact that American Industrial genius ran along lines favorable to the development of the former, and unfavorable to the development of the latter.

It had been assumed by some that it would be an easy and natural matter for electrochemists to extend their triumphs in inorganic lines to organic lines; but with this view the speaker did not agree. With a relatively few exceptions, the obvious applications of electrochemical methods to organic industry (putting aside the use of electrochemical products such as chlorine, caustic, so-

dium, carbide, etc., in organic industry) were largely confined to the conversion of one intermediate product into another intermediate product; and as in such cases it would rarely happen that the electrochemist could feel on safe ground either as to his supply of the raw intermediate product, or as to the market for his finished intermediate product, the electrochemist was usually too much of a business man to enter a field of that kind. Consequently it must be left largely to the organic chemist, since it was under his purview that the commercial aspects of such change of products came.

The speaker compared, on the basis of reductions and oxidations equivalent to a gram molecular weight of hydrogen, energy costs involved in electrolytic methods with power taken at various figures, with the cost of chemical reducing and oxidizing materials. He showed that under most conditions a fair margin apparently existed, with the exception of the very cheapest reducing materials, such as iron, in favor of electrochemical methods. The difference was particularly marked in the case of oxidations, and the same remark would, of course, apply to substitutions.

However, two facts were to be set against this. In the first place, to do a unit of chemical work in unit time an electrolytic plant would usually be very much larger than a chemical plant; require very much more room; be very much more expensive; require more expert attention, and on account of the extreme severity of the demands of electrolytic methods on materials employed for plant, etc., the upkeep would also usually be higher.

In the second place, the working out of an electrolytic method requires a very much greater amount of time, thought intelligence and expenditure than the working out of a chemical method. Though this might not amount to much as regards laboratory investigation, anyone acquainted with the electrolytic industries would be aware of the greater difficulties which invariably had to be overcome in preparing such a process for large-scale operation, and in that important phase known as "establishing practice."

While American industries led the world in the application of intelligence to such industrial problems as were conducted on a sufficiently large scale, we had apparently not yet reached the stage where the same grade of intelligence was being applied to problems of smaller dimensions. This was one of the principal reasons for the difference in success between the inorganic electrochemical and the synthetic organic chemical industries in this country. It would be one of the things militating against a considerable adoption of electrochemical methods in the organic industries, as most of these applications would relate to problems individually of small commercial importance.

Lastly, Mr. Lidbury expressed considerable doubt as to whether organic chemists would be capable of themselves applying electrolytic methods to their own problems. An organic chemist was usually constitutionally unfitted to be any other kind of a chemist. It was, therefore, his recommendation that where there appeared to be a field for application of electrolytic methods, electrochemists should be employed for investigation purposes; and that they should be given not merely a specific problem to work out, but the run of the whole particular field involved, since electrochemistry was not so much a collection of methods as a habit of thought.

Electrolytic Preparation of Organic Compounds

The next paper was presented by Dr. HAROLD HIBBERT, of the Mellon Institute of Industrial Research on "the electrolytic preparation of organic compounds."

A review of the literature and patents published during the last twenty-five years brings out one fact very clearly, namely, that, as in so many other branches of

the chemical industry, the honor of being the pioneer in this development of the art belongs, one might say, almost exclusively to Germany. During the period under review (up to the end of 1910) some eighty-nine patents on this subject were granted in Germany, six in France, three in England and four in this country.

An analysis of the eighty-nine German patents shows that some fifty of these are concerned with the synthesis of dye-stuffs, or intermediate products concerned in the manufacture of dye-stuffs, as indicated in the following table:

Subject.	Total Number of Patents
Reduction of aromatic nitro compounds.....	39
(a) Reduction of nitro derivatives to give azo and hydrazo compounds.....	13
(b) Nitro derivatives to give amines (aniline, benzidine, m. phenylene, diamine, etc.).....	6
(c) Nitro derivatives into nitroso compounds.....	1
(d) Nitro derivatives into amido phenols.....	12
(e) Reduction of azo and hydrazo derivatives to give amines (benzidine, etc.).....	6
(f) Reduction of azo derivatives to give hydrazo compounds.....	1
	39

In addition to these patents there are between ten and fifteen concerned with the synthesis of various special products, as, for instance, the reduction of indigo, oxidation of alizarin and the direct formation of azo dye-stuffs.

The remaining patents have reference to various minor applications, such as the manufacture of iodoform, saccharin, vanillin, phthalic acid, etc. It will be noted that only in a very few instances has it been found possible to apply the electrochemical methods to the synthesis of aliphatic compounds.

In the author's opinion the wonderful progress associated with the caustic alkali-chlorine industry is to be connected principally with two factors: (1) The entire absence of a monopoly of the raw product. (2) The general demand in practically every branch of the chemical industry for these products.

Three factors are necessary for the development of any (synthetic organic) chemical industry: (1) Cheap fuel. (2) Cheap transportation. (3) Other factors, e.g.: (a) An ample supply of raw material obtainable at a sufficiently low cost; (b) satisfactory patent protection; (c) absence of inimical legislation.

In the writer's opinion there would seem to be no question but that a very considerable number of intermediate products required in the synthetic-dye industry could be manufactured in this country with satisfactory financial returns. It is of interest that the German patents on the principal processes have already lapsed. While most of the patents issued up to the present are concerned either with processes of oxidation or reduction, there would seem to be also a considerable field for the application of electrolytic processes to the synthesis of "substitution" products, that is, to the manufacture of chlorinated compounds of various descriptions, etc., but this will require an extended study of the technique suitable to the particular problem to be solved. However, in view of the great desire on the part of the electrochemists to find an outlet for the surplus chlorine produced in the manufacture of caustic alkali, it would seem probable that before long attention will be directed to this field as a possible outlet. Of the various processes, which have already been shown to be highly profitable commercially, coming to the writer's knowledge, those of iodoform and para-hydroxy-amino compounds would seem to form the most striking instances.

The best process for making iodoform would seem to be that developed by Foerster and Mewes.¹ A solution containing five parts of sodium carbonate, seventeen parts potassium iodide, ten parts 96 per cent alcohol and 100 parts water are electrolyzed, using smooth sheet

platinum as anode and sheet lead as cathode. The temperature is maintained at 60-70 deg. C., with a current density of 1-2 amp per square decimeter. In order to avoid losses, due to reduction, the cathode is covered with parchment paper. Carbon dioxide is conducted into the solution at such a rate that this retains a distinctly yellow color. Iodoform settles at the bottom of the vessel in a perfectly pure state and, employing a current density of 1 amp per square decimeter, a yield of 95-97 per cent, calculated on the current used, is obtained. One kilowatt-hour gives about 500 grams of iodoform.

Apparently the simplest process for the preparation of amino phenols would seem to be that of F. Darmstaedter,² which consists in electrolyzing a suspension of nitro benzol in 50 per cent aqueous sulphuric acid. The two poles are separated by a diaphragm and it is necessary to agitate very vigorously. The cathode consists of carbon, the anode of platinum and a current density of 6 amp per square decimeter is employed. Using an excess of nitro benzol, it is stated that a yield of para-hydroxy-amino phenol up to 86 per cent can be obtained.

Another possible application of electrochemical methods would seem to lie in the utilization, for example, of waste dilute nitric acid for the manufacture of nitro compounds, as for instance the manufacture of nitro naphthalene according to Tryller's method,³ which consists in agitating vigorously one part of molten naphthalene with fifty parts of dilute nitric acid at a temperature of around 82-85 per cent C. The electrolysis is carried out using a platinum cathode and aluminium anode. It is not necessary to use a diaphragm. The mono-nitro derivative, practically free from dinitro, is obtained in this way.

The Electrolysis of Aromatic Compounds

Dr. GEORGE SHANNON FORBES, of Harvard University, presented a paper on "The Electrolysis of Aromatic Compounds," which was illustrated in a very interesting way by numerous experiments.

The typical reactions in the electrolysis of aromatic compounds are oxidation, substitution and reduction. Typical oxidations are those of aniline to aniline black, and indigo white to indigo (the first recorded experiment of this kind, Grothius, 1807) which were demonstrated by Dr. Forbes by experiment. Important financially are such reactions as the oxidation of benzene to quinone, with subsequent reduction to hydroquinone, the oxidation of anthracene to anthroquinone, and that of o-toluene-sulphamide to saccharin.

In substitution an ion like Cl^- or Br^- may be discharged and act directly, or through migration of anions, like SO_4^{2-} , NO_3^- , or NO_2^- the concentration of a molecular species may become so great on the surface of the anode as to cause reaction. This was illustrated by the preparation of Orange II.

Electrolytic reduction was illustrated by the preparation of azobenzene from nitrobenzene at a nickel cathode, and by the reduction of pyridine to piperidine at a lead cathode. The familiar scheme of reduction of nitrobenzene both in alkaline and in acid solution was discussed.

The great number of variables in electrolysis, such as electrode material, overvoltage, current density, catalysis by the electrode or by dissolved substance, the differing effects of temperature on primary and secondary reactions, added to the variables significant in ordinary organic work, make the situation very complicated, but in these very complications lies the possibility of preparing compounds from costly materials, with greater efficiency and profit than is possible by the ordinary methods of organic chemistry. It appears probable that

¹Zeit. für Electrochemie 4, 268, 1897.

²D. R. P. 181,116 (1903).

³D. R. P. 100,417 (1897).

in cases like this, the difficulties and disadvantages of the electrochemical method will be outweighed, and that electrochemical methods will prove of the greatest value.

A general discussion of the subject followed in which Messrs. Bogart, Baskerville, Doremus, Richards, Hooker, MacDowal and others participated.

The Fixation of Atmospheric Nitrogen*

BY W. S. LANDIS

Chief Technologist, American Cyanamid Company

I assume more or less familiarity with the use of nitrogen in one or more of its various combinations, for even a partial catalog of the most common commercial nitrogen compounds would read like a few pages out of *Olsen's Chemical Annual* or the *Chemiker Kalender*. I will not even give statistics of consumption of the nitrogen compounds, because the very complex nature of these statistics would make them difficult of comprehension if merely read from prepared tables. I need but say that in tonnage alone the nitrogen compounds stand well at the head of the list of the world's trade in heavy chemicals, nitrate of soda and sulphate of ammonia being produced in 1913, to the value of \$200,000,000.

Chilian Saltpeter and Coke-Oven Ammonia

Not including atmospheric nitrogen, whose utilization is yet in its infancy, we are practically dependent for our supply of this valuable element upon the nitrate deposits of Chile and upon its recovery as a by-product from our fuels. The Chilian deposits have been so frequently and fully described elsewhere that we can omit reference to the same here. The end of this source of supply is, however, in sight, and it will only be a few years until Chilian nitrate will pass into history along with our anthracite coal and the Saxon silver-lead ores.

The recovery of ammonia as a by-product from fuel is entirely different, for in the coke oven and the gas producer we will have an ever-increasing source of this element for many centuries to come, from which it is obtained in one of its most valuable forms of combination, ammonia. This source of supply is, however, somewhat unsatisfactory, inasmuch as it is wholly a by-product of the coal distillation industry, a ton of coal yielding only 5 to 6 lb. of ammonia, and by-products as a source of primary supply have many limitations. This is well illustrated by the present status in Germany, from which country I have lately returned. There is in that country just now a considerable shortage of nitrogenous fertilizer because the Government has confiscated all stores of nitrate for military purposes. (The fertilizer industry there consumes about 800,000 tons of nitrate per year.) The coke ovens which we should expect would normally come to the rescue in such a crisis are, however, largely closed. Ammonium sulphate production is, therefore, correspondingly decreased just at a time when agriculture needs it most, and its lack is felt acutely. Since my return I have learned that the use of coal has been prohibited in Germany in order to force the use of coke and thus increase the supply of ammonia and tar.

We came very near having the same conditions arising in this country, for were the farmer in position to take his normal fertilizer requirements there would be a great sulphate shortage, as our own industrial depression has closed down many of our coke ovens, and we would have no ready means of meeting even a normal demand for sulphate. We thus see the disadvantage of

a by-product source of such an important element as nitrogen, and we understand why inventors have turned so actively to finding a substitute for the Chilian nitrate and the coke-oven ammonia.

Fixation of Atmospheric Nitrogen

Naturally the inexhaustible store of atmospheric nitrogen has presented itself most prominently in this search for a new source. Neglecting the many proposals which have merely wasted much paper and ink in describing impossible methods for the fixation of our atmospheric nitrogen, I am going to devote my attention solely to the successful and at the present time commercially developed efforts in this field.

We can classify these successful attempts into three groups:

1. Direct synthesis of nitrogen and hydrogen to ammonia.
2. Combustion of nitrogen and oxygen in the electric arc.
3. Combination of nitrogen with metals or carbides.

Synthetic Ammonia

The only commercial process to-day, belonging to group 1, is the so-called Haber process. Dr. Bernthsen (this journal, Vol. X, p. 637, 1912) described this process at the Eighth International Congress of Applied Chemistry, and exhibited a small working model of the apparatus. I am sorry that I can add but little to the technical information he there presented, but the owners of this process have maintained the greatest secrecy with respect to its commercial development, and but little is known regarding the details in the commercial world.

As you will recall, this process consists in passing a mixture of three volumes of hydrogen and one volume of nitrogen, at a pressure of upward of 150 atmospheres over a suitable catalyzer operating at a temperature of some 500-700 deg. C. A single passage of this mixture through the apparatus causes a transformation of 2 per cent to 6 per cent of the nitrogen to ammonia, which is recovered from the apparatus by condensation and the rest of the uncombined gases are again returned to the cycle.

Too much honor cannot be shown the courageous chemists who have succeeded in placing this process on a commercial working basis. The difficulties seemed almost insurmountable. The catalyzer, which has taken various forms and compounds, principally metals and carbides, poisons very readily, and, therefore, extreme care must be taken in the purification of the gases. Purity which the average chemist would classify as C. P. finds no place in this industry, as that would lack almost as much of meeting the requirements of the process as the use of crude chemicals in the analytical laboratory. It took years of work to find a suitable metallic container for the high-pressure gas mixture, because of the permeability of most ordinary materials. However, most of these difficulties have been overcome, and I have been reliably informed that the Badische plant at Oppau supplied its allotted quota of sulphate to the German Sulphate Sales Company last year, but I greatly doubt that they did it at a profit if it was made from synthetically produced ammonia, with sulphate prices as low as they were in the early part of 1914.

This process as ordinarily understood is not supposed to involve the use of any considerable quantity of electric power (which is not quite true), but does require a large amount of highly skilled labor, for the units are small and complicated. This particularly suits it to the Rhine location, but renders its value in the United States rather questionable. I personally cannot see a future

* A paper presented before the Washington Section of the American Chemical Society on March 15th, 1915, and before the Philadelphia Section of the American Chemical Society on March 18th, 1915.

for its operation under American conditions, particularly in view of the competition of the much cheaper cyanamid process which furnishes the same end product—ammonia.

At Oppau the Badische company must dispose of large quantities of waste sulphuric acid and have a by-product hydrogen, hence local conditions favor the Haber process above all others.

Direct Combination of the Nitrogen and Oxygen in the Air

The second group of processes embraces those oxidizing the nitrogen of the atmosphere in the electric arc. It is well known that when air is heated to temperatures of about 1800 deg. C., the nitrogen oxidizes to NO and remains, on rapid cooling, in that form. At that temperature, however, the reaction velocity is very low and commercial working requires that temperatures of above 3000 deg. C. be used, at which temperature the reaction velocity becomes quite considerable.

Three types of apparatus are in commercial use for performing this reaction:

1. The drum furnace with disk arc, of Birkeland and Eyde.
2. The long tube furnace with spiral arc, of Schön-herr.
3. The narrow furnace with fan-shaped arc, of Pauling.

There are numerous other proposed types of apparatus which are claimed to be superior to the above, as reference to patent literature in particular will show, but the above listed three furnaces are the only ones in actual every-day operation.

The product obtained by passing air through the arc of any of these furnaces consists of a highly heated gas containing from 1 to 2 volume per cent of nitric oxide. On cooling down to temperatures of approximately 600 deg. C., this nitric oxide unites with free oxygen to form nitrogen peroxide, NO_2 ; on further cooling of this nitrogen peroxide to below 140 deg. C., it polymerizes to N_2O_4 . When brought into contact with water and oxygen this reacts forming a mixture of equal molecular parts of nitric and nitrous acids. By subjecting the nitrous acid to further action of the peroxide this is also changed to nitric acid with the liberation of nitric oxide, which again passes through the cycle.

Thus by suitable cooling of the nitric oxide in the presence of air and water one ultimately attains a product which consists almost quantitatively of nitric acid, and actual operating results of the large furnace plants have shown a steady recovery of about 90 per cent of the nitrogen oxides in the form of nitric acid or nitrate salts, the remainder being received as nitrite or not absorbed.

In general the handling of the nitrose gases from the arc furnaces is now well standardized, and the design of a condensation plant is almost as well understood to-day as that of a sulphuric acid plant. After passing the various systems of cooling apparatus, consisting of steam boilers, evaporators, etc., the gases enter aluminium condensers where the temperature is reduced to approximately 100 deg. C. They then enter a preliminary oxidation chamber so proportioned that they remain in the same at least one and one-half minutes before leaving, where the preliminary oxidation to peroxide takes place. The gases next pass into a series of four or five stoneware or granite towers where they are washed with water by a counter current system, remaining in the tower system for from three to five minutes. Of the nitrogen oxidized 90 per cent is here condensed as nitric acid, the most concentrated acid being obtained in the first tower, and averaging from

30 to 35 per cent HNO_3 . After passing these condensing towers the gases usually enter a final tower fed with caustic soda liquor, where a further 3 to 5 per cent of the oxidized nitrogen is recovered as sodium nitrite. The remaining 5 per cent passes out into the air unabsorbed.

As above mentioned, these towers deliver a 30 to 35 per cent nitric acid; this can be further concentrated to 50 per cent nitric acid, using the heat of the hot gases issuing from the arc furnace to perform the necessary evaporation. It is not possible to carry this evaporation much above 50 per cent for economical reasons, and where higher concentration of nitric acid is demanded special complicated concentration processes must be employed.

Dilute nitric acid, as obtained from the towers, finds little use in industrial processes, and it is difficult to transport. Most of the nitric acid plants, therefore, either concentrate it to 96 per cent acid by special means, or convert it into calcium nitrate for fertilizer use, or into ammonium nitrate for explosive purposes. In the latter case most of the ammonia used to-day in the nitric acid plants, operating on the arc system, is obtained from cyanamid.

It is quite probable that calcium nitrate will soon disappear from the fertilizer market as it certainly cannot be sold at a profit in competition with Chilean nitrate or ammonium sulphate even when the latter is made from cyanamid.

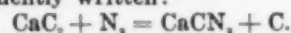
As we shall see later these arc processes require enormous quantities of cheap electric energy, and must be located near such power centers. We have no cheap power in the United States, and there is no immediate prospect of our having an arc process in continuous large-scale operation within our borders. Our Western powers are far from markets and transportation of the nitric acid as such to the East is almost out of the question.

Cyanamid Process

The third group of processes, as catalogued in my introduction, embraces fixing nitrogen by metals or carbides, and has reached its highest development in the cyanamid process, which last year produced throughout the world in the fourteen factories at present in operation, some 300,000 tons of material, carrying over 20 per cent nitrogen.

The inventors of the cyanamid process originally attempted the synthesis of cyanides by subjecting barium carbide to the action of nitrogen, which, as is well known, forms barium cyanide. On attempting to use the cheaper calcium carbide in place of barium carbide, Professors Frank and Caro found that instead of obtaining cyanide they obtained a new material, which proved to be calcium cyanamid. It was later found that this material could be utilized directly in agriculture, and from this discovery has grown the enormous cyanamid industry which has proven itself to be the cheapest method of fixing atmospheric nitrogen at present in existence.

Reference to the literature existing upon the manufacture of cyanamid seems to lead one to suppose that it is a comparatively simple matter to carry out the reaction so frequently written:



This might be true to a limited extent were this the only reaction that we chemists at Niagara had to contend with, but I can merely say to you that even this reaction itself is so complicated that while it is well known that it is a reversible one, no one has yet succeeded in correctly establishing its equilibrium constants. A laboratory study of this reaction has been

carried out both in this country by Prof. M. de Kay Thompson (this journal, Vol. VIII, p. 617 and 687, 1910), and abroad by Professor Haber, but neither of them has succeeded in mastering the same, because of the peculiar difficulties that arise in a study of it.

Naturally if the highly skilled chemical laboratories have met with these difficulties, we can assume that practice runs against a few of them itself. But aside from the fundamental absorption reaction, as written above, there are a number of other complications that arise in this industry which we have to meet with in our every-day work, and which I shall call to your attention to show that the actual carrying out of the cyanamid process requires something more than writing the reaction on a piece of paper.

The fertilizer industry, into which most of our ma-

furnaces and methods of operation. We had to seek sources of raw materials for this manufacture, which are quite different even from those which meet the requirements of the manufacture of lighting carbide, and we have to operate our furnaces in a certain peculiar way in order to combine these raw materials into a product of such structure and grade that we can make cyanamid out of it successfully. As may be recalled, Moissan in his early work found that he could not nitrify certain kinds of carbide, showing that there are conditions existing in our carbide manufacture that are different from those in the manufacture of lighting carbide.

Our next great problem was to grind this special grade of calcium carbide so that it passes a hundred-mesh screen. Naturally this must be done without

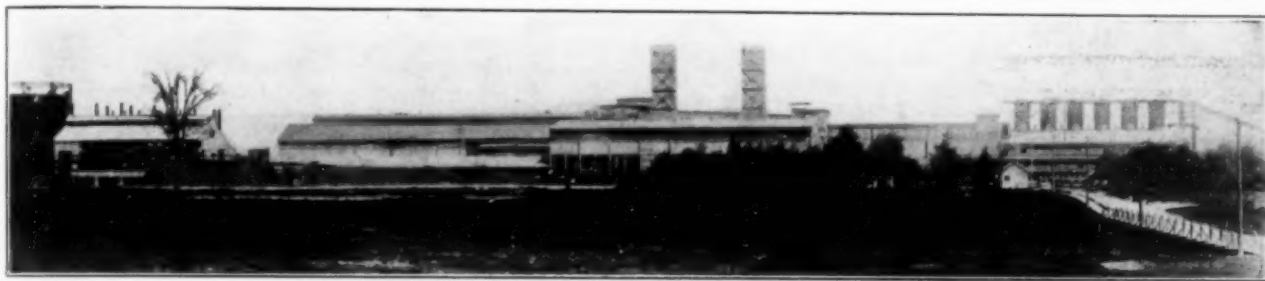


FIG. 1—AMERICAN CYANAMID COMPANY'S WORKS AT NIAGARA FALLS—LIME PLANT AT THE EXTREME RIGHT; COAL-GAS PLANT AT THE EXTREME LEFT; CARBIDE AND CYANAMID BUILDINGS IN CENTER

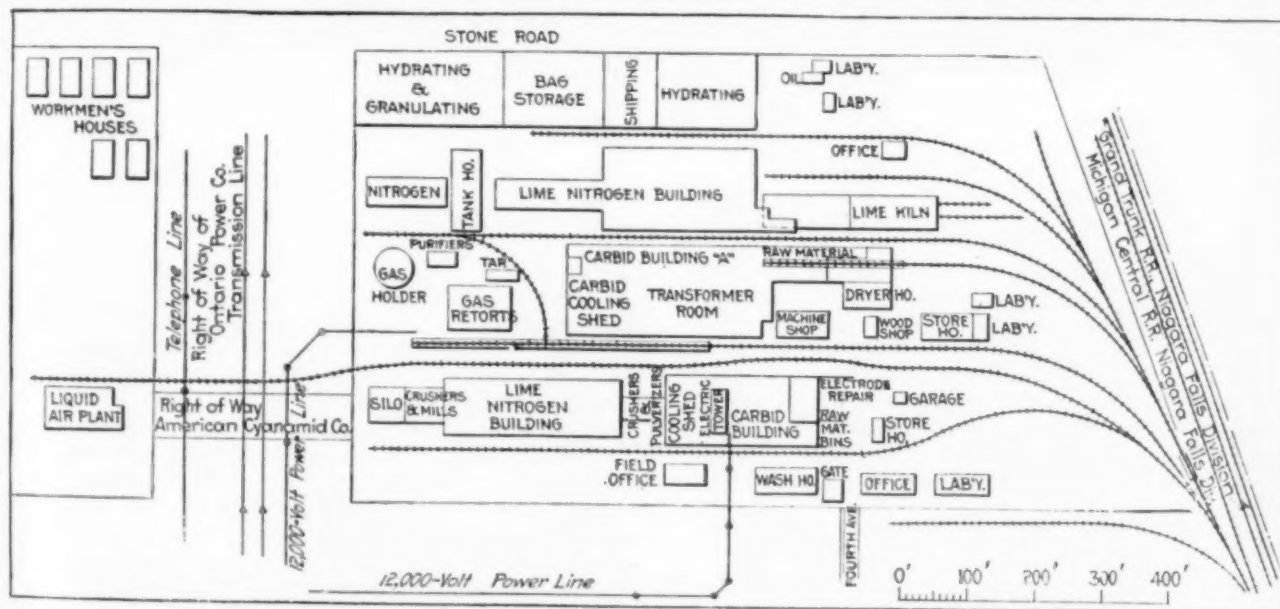


FIG. 2—PLAN OF AMERICAN CYANAMID COMPANY'S WORKS AT NIAGARA FALLS, ONTARIO

terial at present goes, is a rather peculiar one, and probably has more peculiar fads and precedents than almost any other highly developed industry in the country. Naturally to sell to fertilizer men material we must take into account all of the peculiarities of the industry, and we must satisfy them—a fact which further complicates the cyanamid industry itself. But it may be assumed that inasmuch as cyanamid is being produced and sold at the rate previously mentioned we have succeeded somewhat in meeting these fancies.

The first stage of the cyanamid process involves the production of calcium carbide. To produce day after day a high-grade calcium carbide that meets the peculiar requirements of the cyanamid industry is quite an art in itself. There are no journeymen carbide workmen in our country, and we had to start out and develop our own

slacking the carbide, as hydrated lime does not make good cyanamid. Now 100-mesh carbide dust is almost as explosive as low-grade dynamite when exposed to the atmosphere on a damp day, or thrown out on damp ground, so that it is quite some little problem of itself to grind this carbide to the required degree of fineness and have a mill left at the end of the day's run.

Next comes the production of nitrogen. It is a comparatively simple matter for the chemist to make a few cubic centimeters of high-grade nitrogen in his laboratory, but if one were to call upon him for 2,000,000 cu. ft. of a practically pure nitrogen per day, such as we make at Niagara, he would probably have to do considerable research to find out just how this enormous quantity of such high-grade material could be made. In the early days of the cyanamid process, when the Ni-

agara plant started, liquid air machinery was in a rather backward state of development, and we were forced to make our nitrogen by passing air over copper. The original plant was later enlarged. It was a long step from the combustion tube of the chemical laboratory to our present plant using retorts containing 5 tons of copper mass, but the problem has been successfully solved, and the new plant has been in operation with a minimum of trouble for some years.

In the early days of the industry at Niagara we could draw upon natural gas for reducing our copper oxide, so as to revivify it, but this gas supply has since failed and we were forced to put up our own coal gas plant. Even this coal gas plant is not a standard one, inasmuch as we are coking coal, not only for the production of gas, but also to furnish the coke for our carbide furnaces. We are running at temperatures in our retorts and obtaining qualities of coke and gas that the average city gas plant would not consider as possible of attainment, and it was only after considerable experiment that we ourselves demonstrated that our theories were correct in this respect and succeeded in finding gas engineers liberal-minded enough to incorporate our ideas into a working plant.

Eventually we had to install purification apparatus for taking out the impurities in the nitrogen, as it came from the copper retorts, and have equipped ourselves with soda towers for removal of carbon dioxide, refrigeration plants for drying, lime tanks for purification, etc., and have even developed this plant so highly that we have included a causticizing plant for recovery of our spent alkali.

After the development of the liquid air machinery, both in the way of capacity and reliability, the problem of producing pure nitrogen was much simplified, and our latest addition at Niagara includes what was probably the largest liquid air plant in the world at the time it was built, a year ago. This plant alone throws to waste almost 30 gal. of liquid air an hour, just to keep the apparatus flushed out and in good working order, not to speak of the thousands of cubic feet of rich oxygen-nitrogen mixture.

After one has overcome the difficulties in the production of a proper grade of nitrogen and of carbide, the next step is exposing these two to mutual reaction at a proper temperature, which is done in small individual ovens, holding from $\frac{1}{2}$ to $2\frac{1}{2}$ tons of carbide. The reaction itself is reversible, and particular precautions must be taken to always keep it running in the right direction until the carbide has all been nitrified. The physical and chemical conditions which must be met with in this part of our work are very complex.

The product removed from these ovens is a black, hard cake, which analyzes 22 per cent nitrogen and about 1 per cent un-nitrified carbide. This material, which we call "lime nitrogen," is next finely ground and stored in silos. The carbon set free in the reaction previously indicated is in the form of graphite, and it is not an easy proposition to find a satisfactory mill that will grind this material fine and at the same time not blow itself up from liberated acetylene derived from the presence of any uncombined carbide, or wear itself out grinding the lime nitrogen-graphite mixture. Extreme precautions are taken in this part of our operation, both in the mills themselves and in the elevating and conveying apparatus connected with them to avoid dangerous explosions, but I can truthfully say that in the years I have been connected with the company not a single injury has resulted from such explosions in our plant.

To prepare the lime nitrogen for agricultural purposes the finely ground material is partly hydrated to

insure decomposition of the carbide it contains, and is then oiled to render it dustless, and stored in bulk, or packed immediately into sacks and shipped to the fertilizer mixer.

Calcium cyanamid tends to transform itself into a large number of organic compounds when subjected to the action of water, particularly at temperatures above normal, and, therefore, this hydration has proven an extremely complex problem, because we desire to avoid any such transformation, as agricultural experiments have shown that the calcium cyanamid in its unaltered form yields the best crop results.

Ammonia from Cyanamid

But agricultural uses are not the only purposes to which the cyanamid can be applied, as it is a very simple matter to convert the cyanamid into ammonia by the exothermic reaction



If lime nitrogen is mixed in a slurry with water and subjected to the action of heat and high pressure, it is converted quantitatively into ammonia. In this country this use of cyanamid was not developed on a large scale outside our experimental laboratory until the beginning of this year, but while I was in Germany I saw in the yards of a big manufacturing concern there some sixty autoclaves, each capable of converting 10 tons of cyanamid into ammonia per day. This equipment was waiting railroad cars to move it out, and was in no sense experimental, because three similar plants have been in operation in Germany for at least three years. The cost of this transformation is hardly appreciable, and the purity of the product is quite high, requiring merely passing through a self-acting rectifying column for the removal of steam.

A New Ammonia-Phosphate Fertilizer

The ammonia so produced abroad is at present converted into a high-grade sulphate and a pure nitrate, and we are at work now in this country on producing a new fertilizer material, "ammophos," consisting largely of ammonium phosphate; my experimental laboratory at present working day and night trying to meet initial demands for this new material. Agricultural results the past season have been so phenomenal that our friends will not await the completion of a large plant for meeting the requirements, but have insisted on our converting our laboratories into a miniature factory.

Our product contains over 13 per cent NH_3 and 45-50 per cent P_2O_5 , or over 60 per cent plant food, the bulk of the remainder being chemically combined water, and when mixed with the high-grade potash salts available will make a complete fertilizer some six times as concentrated as the average grades sold to-day.

Urea, Dicyandiamid, and Creatin from Cyanamid

It is also possible to transform cyanamid into urea, and I have made in my experimental laboratory a great deal of pure salt in a comparatively easy and simple manner.

Similarly it can be converted into dicyandiamid by simple treatment with hot water. This material has been proposed for use as a deterrent in explosives, but which I think offers a much better field for transformation into the guanidines.

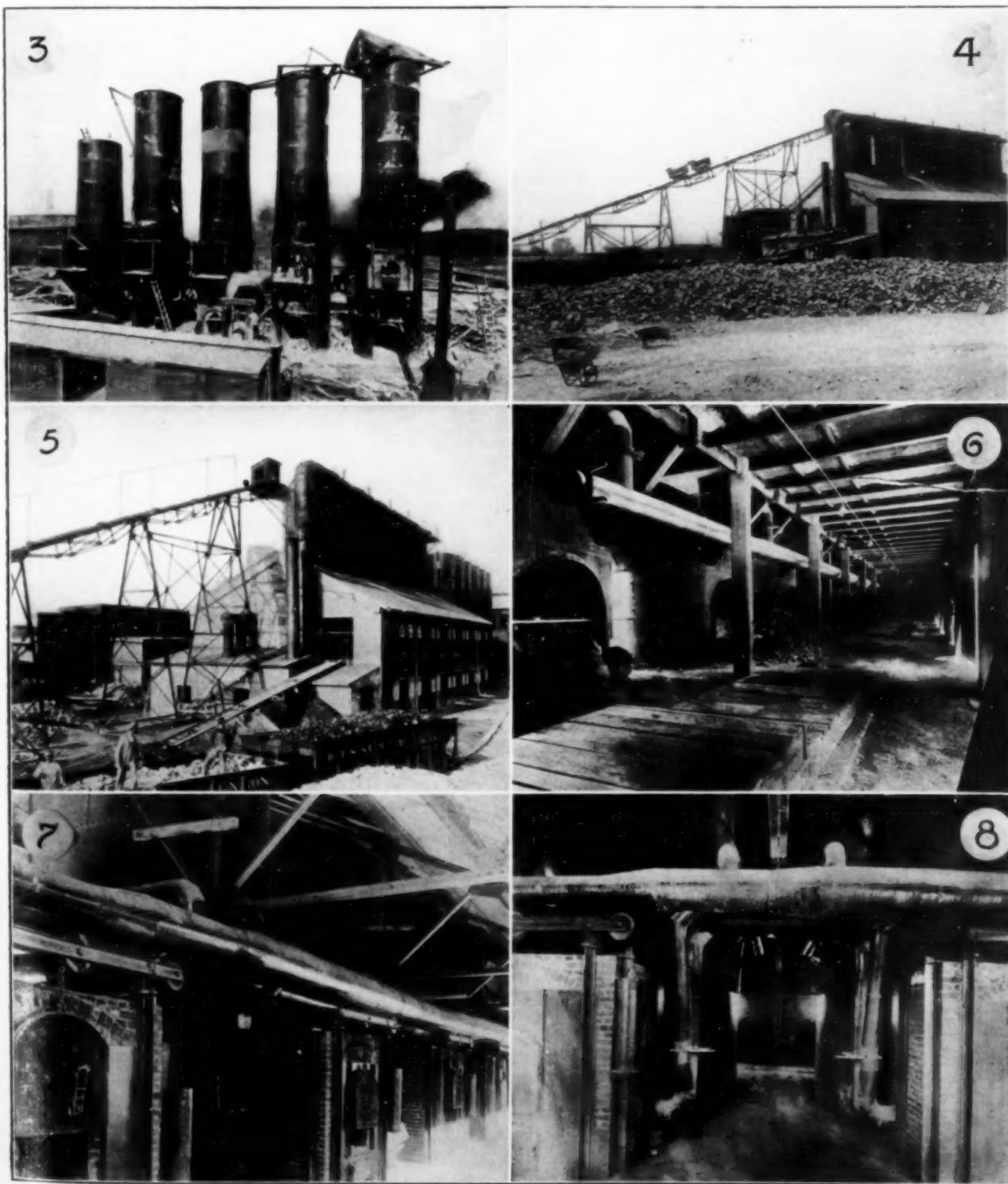
Such transformations of cyanamid abroad have received a great deal of attention, and there are numerous derivatives on the market. Just a few months ago I saw a sample of creatin which had been made in a chemical laboratory from cyanamid, and we feel that we in the industry are not very far from the synthetic production of foods when we can reach such a point in our chemical synthesis.

Cyanide from Cyanamid

When a special grade of cyanamid is melted down with a flux, such as common salt, it combines the free carbon present with the cyanamid radicle, forming cyanide. The resulting product of this fusion contains about 25 per cent of its weight in equivalent potassium cyanide; this crude form of cyanide dissolves very readily in water and filters rapidly from the insoluble, after which the solution is ready for metal extraction,

or other uses to which cyanide in its dissolved form can be put.

Large scale experiments have been tried out in a number of the big cyanide plants scattered at various places throughout the world, and in every respect this material has shown an exactly equivalent value to the higher grade cyanides. The transformation of the cyanamid nitrogen into cyanide nitrogen is almost quantitative, and the fusion experiments can be carried out



FIGS. 3 TO 8—LIME PLANT OF AMERICAN CYANAMID COMPANY

Fig. 3: Kilns in course of construction with shells erected and fire-clay lining started. Fig. 4: Finished lime plant showing piping for induced draught and Eldred process. Fig. 5: Old lime plant with new addition, and railroad cars. Fig. 6: Lime discharge floor. Fig. 7: Firing floor with piping for Eldred process and counterweight arrangement for charging door. Fig. 8: Arrangement of the return CO_2 and hot-air pipes and damper control for Eldred process.

without difficulty and at a low cost. We have here, therefore, a crude form of cyanide which can be prepared very cheaply and which could be readily delivered to the consumer at a price approximately one-third under the present prices of the higher-grade cyanide.

Abroad this material has been made in large quantities and transformed into the pure cyanide running approximately 127 per cent potassium cyanide equivalent, but we believe that with proper propaganda work our own cyanide users would find the low-grade material quite acceptable, provided it could be delivered to them at a cost sufficiently low to enable them to perform the extra dissolving and filtering operation which it involves over the use of the present high-grade alkali cyanides.

Cyanamid for Case Hardening

Cyanamid itself forms an excellent case-hardening material, and we have prepared a number of mixtures which are in steady use at our plant for performing this operation upon various machine parts which we are using. It works extremely rapidly at very low temperatures, but we have not yet succeeded in overcoming certain fads in large scale use of this material, and it has not met with any general introduction. We found the case-hardener is more concerned with the color of his hardening powders than he is with the actual work they perform, and as the colors and odors of our cyanamid products are rather fast we have not found it interesting to us to meet some of these peculiarities of the case-hardening trade. While abroad I saw these case-hardening materials being prepared by the hundreds of tons for use in the manufacture of armament and war materials, and the small factory engaged in their production has been swamped with orders ever since its inception.

Comparison Between Different Processes for Fixation of Atmospheric Nitrogen

The arc processes have shown themselves capable of producing nitric acid or nitrates; cyanamid itself is an entirely different product, but it is quite easy to produce ammonia from it, and there has recently been evolved abroad a most successful method* of oxidizing this ammonia to nitric acid, so that in case of competition with the Birkeland-Eyde process we are not entirely limited to the fixation of nitrogen, but can furnish this nitrogen in exactly the same form that the arc processes can, and at considerably less cost.

The raw materials for cyanamid are cheap—coke, limestone, air. We use only one-fifth the electrical power that the arc processes do per unit of nitrogen fixed in the form of cyanamid, respectively ammonia, and by the addition of a very small percentage more power we can convert our cyanamid into nitric acid. We require about the same quantity of labor to fix a unit of nitrogen in cyanamid as the arc process does in nitric acid, but since there is only a small fraction more labor used to transform cyanamid nitrogen into nitric acid we do not feel this is a great handicap when one considers our smaller power consumption. On the American continent, where water power is so expensive and so scarce, this difference readily offsets the additional labor necessary to make nitric acid from cyanamid.

Further, our cyanamid is easily transported and can be changed to ammonia or nitric acid at the end of its journey at the expenditure of a very small amount of steam and labor, so that we have the additional advantage in transportability of stable raw material, and subsequent conversion at the point of direct use. These

commercial transformation units are small, and can be set up to supply even small amounts of ammonia or acid in a quite cheap and efficient plant. Practically all sulphuric acid plants in Germany have installed them since nitrate has disappeared from the trade.

There is no comparison between the initial investment required for a cyanamid plant and for an arc plant if one will include power development. The cyanamid plant, per unit of nitrogen fixed, requires an investment of only about one-quarter that required by the arc process, and for a cyanamid-ammonia plant about one-half that required by the Haber process. Even the combination of the cyanamid-ammonia-nitric acid process requires an investment of only one-third to one-half that for the arc process. In each case we are assuming exactly the same quantity of fixed nitrogen in the forms above designated.

Where electrical power is expensive, as in the United States, there is no question regarding the superiority of the cyanamid process for the fixing of atmospheric nitrogen, particularly for fertilizer purposes, and we eventually hope that the future development of our nitric acid process will enable us to compete in every line of nitrogen compounds with all other competitive sources.

* * *

The Niagara Falls Plant of the American Cyanamid Co.

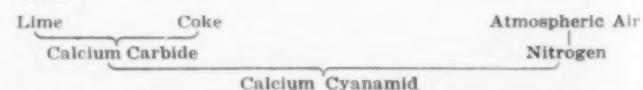
Mr. Landis illustrated his paper by a series of very interesting moving pictures, showing the most important steps in cyanamid manufacture at Niagara Falls.

As a substitute for the movies we give some representative views. As the Niagara Falls plant of the American Cyanamid Company comprises a 12-kiln lime plant, 25,000 horsepower of calcium carbide furnaces, a liquid-air plant which was the largest in the world a year ago, a gas plant of sufficient size to serve an average town of 25,000 inhabitants, a nitrogen retort plant, an ammonia refrigeration plant, a causticizing plant, a nitrification plant, a hydration plant, and innumerable crushers, mills, silos and feeding machinery, we cannot do more than give illustrations of some departments, chiefly the gas plant and the lime plant.

Fig. 1 gives a view of the works of the American Cyanamid Co. at Niagara Falls, Ontario, showing the lime plant at the extreme right, the coal gas plant at the extreme left, and the carbide and cyanamid plant in the center. A diagrammatical plan of the arrangement of the whole works is given in Fig. 2, which is reproduced from *Engineering News* of January 7, 1915.

The plant was started in 1909 with an annual output of 12,000 tons of cyanamid. The plant was enlarged in 1913 to an annual output of 32,000 tons, and in 1914 again enlarged so that the output is now 64,000 tons.

The whole operation may be concisely sketched as follows:



Concerning the production of the cyanamid from carbide and nitrogen nothing need be added here to Mr. Landis' paper.

The manufacture of calcium carbide is carried out in continuous operation in eight 20-ton, 3000-hp three-phase electric furnaces, each with three large carbon electrodes at the top. The charging platform for the furnaces is on a level with the top of the furnaces. The transformers are placed below the charging platform close to the furnaces, so as to require only very short connections between furnace and transformer.

*See, for instance, this journal, vol. 11, page 433 and 476, 1913.

Lime Plant.

The lime is burnt in the lime plant which was designed by the Improved Equipment Company of New York City, to whom we are indebted for the photographs reproduced in Figs. 2 to 8. The lime plant consists of twelve Doherty-Eldred lime kilns, equipped with the Eldred process and operated with induced draught. The first installation comprised six kilns, and six more were erected last year.

Fig. 3 shows the kilns in course of construction; the kiln shells have been erected and the fire-clay lining has been started. Fig. 4 is a view of the finished lime plant and shows the piping for induced draught and Eldred process. Fig. 5 is a view of the old lime plant with the new addition in course of erection, and shows the limestone being brought to the plant in cars. Fig. 6 is a picture of the lime discharge floor, Fig. 7 a picture of the furnace or firing floor with the piping for

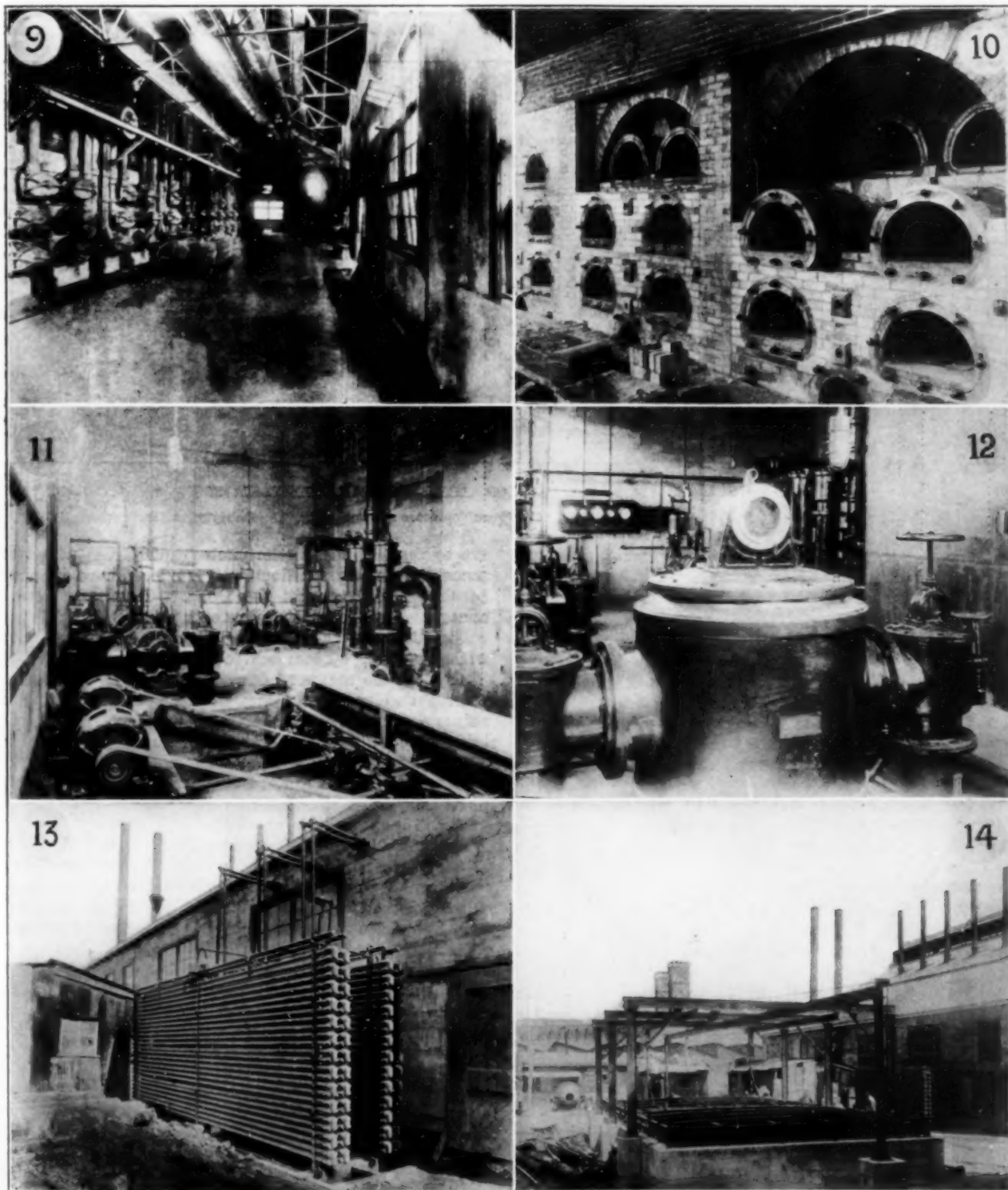


FIG. 9 TO 14—COAL GAS PLANT OF AMERICAN CYANAMID COMPANY

Fig. 9: Charging floor of retort house with conveyor system and coal buggy. Fig. 10: Manner of laying up the sectional silica retorts and settings. Fig. 11: Machinery room with Doherty washer cooler and centrifugal pump. Fig. 12: Rotary meter. Fig. 13: Side view of cooling coils of Doherty washer cooler. Fig. 14: End view of concrete purifying boxes.

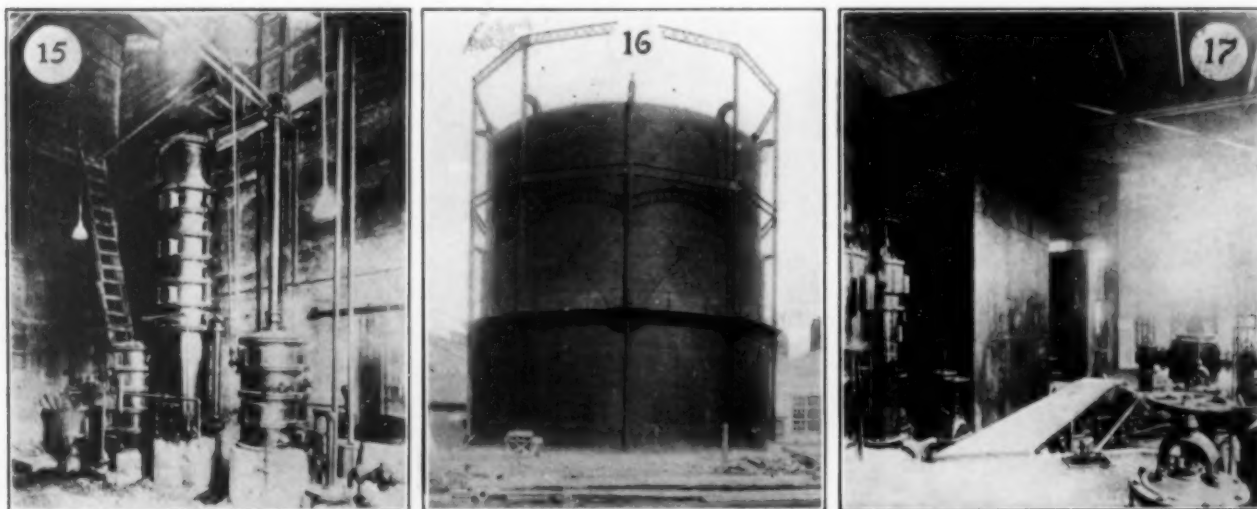
the Eldred process and counterweight arrangement of the charging door, while Fig. 8 shows the arrangement of the return CO_2 and hot-air pipes and the damper control for the Eldred process.

The Eldred process and its applications to lime kilns was described very fully in an article by Mr. Carleton Ellis in our Vol. II, p. 495 (1904). The exhaust gas from the kilns is drawn by an exhaustor from the top of the stacks and part of it is used as a "diluent" for the air in the fire boxes to get correct conditions of combustion. The balance of the exhaust gas is led to the waste stack.

The coke for the carbide manufacture is partly

above, the standard coal gas process is not used; the retort benches are run very hot to produce a gas rich in hydrogen and coke low in volatile matter. They "are running at temperatures in the retorts and obtaining qualities of coke and gas that the average city gas plant would not consider as possible of attainment, and it is only after considerable experiment that we ourselves demonstrated that our theories were correct in this respect and succeeded in finding gas engineers liberal-minded enough to incorporate our ideas into a working plant."

The coal gas plant was installed by the Improved Equipment Company of New York City, to whom we



FIGS. 15 TO 17—COAL-GAS PLANT OF AMERICAN CYANAMID COMPANY

Fig. 15: Ammonia still. Fig. 16: Gas holder of 100,000 cubic feet capacity. Fig. 17: Doherty washer cooler

bought as such and the balance comes from the gas plant to be described later.

Nitrogen from Air.

As explained in Mr. Landis' paper the nitrogen (needed for the reaction with carbide to form cyanamid) must first be separated from the oxygen in the atmospheric air. Two different processes are being used for this purpose at Niagara.

The newer method, installed for the latest extension of the plant last year, uses liquid air produced by the Claude process. The oxygen is separated from the nitrogen by fractional distillation of the liquid air.

The older method used is the so-called copper sponge method, in which retorts filled with copper sponge are employed. When a series of these retorts is heated and air is blown through the copper sponge, the oxygen of the air combines with the copper, forming cupric oxide and leaving the nitrogen free. The flow of air is then diverted to a second series of heated retorts, also containing copper sponge, while coal gas is passed through the first series of retorts so as to reduce the cupric oxide to copper sponge. This is then used again for combining with the oxygen in a fresh amount of air and setting the nitrogen free, and so on. The process is therefore cyclic.

Coal Gas Plant

From the foregoing description it will be seen that the coal gas plant serves a double purpose. It provides coke for the carbide manufacture, and it provides the coal gas for the reduction of cupric oxide in the separation of nitrogen gas from atmospheric air.

The coal-gas plant has a capacity of 500,000 cubic feet per 24 hours. As Mr. Landis explains in his paper

are again obliged for the photographs from which the accompanying illustrations were made. There are seven benches equipped with the Doherty bench fuel economizer and sectional silica retorts and settings.

Fig. 9 shows the charging floor of the retort house with conveyor system and coal buggy, while Fig. 10 illustrates the manner of laying up the sectional silica retorts and settings. Fig. 11 is a view of the machinery room with Doherty washer cooler and centrifugal pump. Fig. 12 shows the rotary meter, Fig. 13 is a side view of the cooling coils of the Doherty washer cooler, and Fig. 14 an end view of the concrete purifying boxes showing covers.

Fig. 15 shows the ammonia still, Fig. 16 the gas holder of 100,000 cubic feet capacity, and Fig. 17 the Doherty washer cooler.

Before concluding this article, attention should be called to an admirable paper by Mr. Frank S. Washburn, president of the American Cyanamid Company, which was presented last month at a joint meeting of the American Institute of Electrical Engineers and the New York section of the American Electrochemical Society, and will come up for discussion again at the annual convention of the American Electrochemical Society at Atlantic City in April. It will be published in full in our next issue. An abstract of this paper, together with an account of another excellent paper, by Mr. Summers, on the general situation in the fixation of atmospheric nitrogen, will be found on page 241 of the present issue.

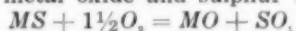
The first authentic discovery of tin in Nevada has been announced by the Mackay School of Mines. Samples from Battle Mountain proved to be stream tin of good quality.

The Formation and Decomposition of Sulphates During Roasting

BY BOYD DUDLEY, JR.

It is the purpose of the writer to present in this paper a general discussion of some of the chemical principles or laws that govern the formation and the decomposition of metal sulphates in the roasting furnace.

When a metal sulphide is heated in the presence of air to its kindling or ignition temperature, which varies with different sulphides and depends to some extent upon the grain size of the material,¹ there are formed primarily the metal oxide and sulphur dioxide,

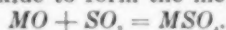


The sulphur dioxide thus formed may be carried as such from the furnace by the excess air, or it may be oxidized to sulphur trioxide,



the oxygen required for this process being derived from the atmosphere of the furnace or possibly from certain metal oxides that are capable of being reduced to lower states of oxidation.

Most metal oxides will, under proper conditions, unite with sulphur trioxide to form the metal sulphate,



In some cases the normal sulphate does not represent the only possibility since basic sulphates may be produced,

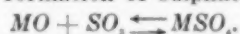


Wherein a and b are small whole numbers, the ratio of a to b being greater than in the case of the normal sulphate. Basic sulphates may, of course, be converted into the normal compounds and the reverse, under proper conditions.

The formation of sulphates according to this series of reactions is of frequent occurrence in the roasting of sulphide ores. Sometimes it is desired to maintain conditions in the furnace that will produce the greatest possible amount of some particular sulphate, for example in the sulphatizing roast of copper ore preparatory to leaching. But when the object of the roast is to eliminate sulphur as completely as possible, the formation of sulphates is undesirable, because in order to secure the desired result they must be subsequently decomposed. From the foregoing it would appear that the subject of sulphate formation and decomposition is one of considerable metallurgical interest, and that an analysis of the laws and principles and facts involved may prove of value.

I. Chemical Equilibrium Conditions

Consider first the general equation that has been used to represent the formation of sulphates,



Such reactions are in general reversible as the equation indicates. Consequently it is possible to dissociate a sulphate into metal oxide and sulphur trioxide as well as to form it from these constituents, the direction in which the reaction proceeds being determined by the conditions imposed. Likewise the formation of basic sulphates from metal oxides and sulphur trioxide and their formation by the dissociation of normal sulphates are reversible reactions.

In addition to the simple dissociation of sulphates it is sometimes possible to effect decomposition by heating to sufficiently high temperatures with silica, ferric oxide, and other substances, forming thereby silicates, ferrites, etc. An example of the practical application of this is the decomposition of lead sulphate by silica in slag roasting. Such reactions as the latter, however, are

practically irreversible under roasting conditions and, therefore, do not possess so great a theoretical interest as do the others that have been mentioned.

Viewed from the standpoint of the phase rule the system composed of a metal sulphate, the oxide, and sulphur trioxide is monovariant, i. e., at a given temperature a definite concentration of sulphur trioxide must be maintained in the gas phase in contact with a metal sulphate and oxide in order to maintain equilibrium. In other words the dissociation tension of a sulphate with respect to sulphur trioxide is constant at constant temperature.

It is not possible with the aid of the phase rule to calculate the values of the equilibrium concentrations or dissociation pressures that correspond to various temperatures; they must be determined experimentally in the case of each compound. However, experiment has shown that the dissociation of a sulphate, whether into oxide or only into a basic sulphate, to be an endothermic reaction. From this fact it is possible to state, with the aid of the principle of Le Chatelier,² that the dissociation tension of a sulphate increases with increasing temperature. It can also be shown that the basic sulphate resulting from the dissociation of a normal sulphate possesses at given temperatures lower dissociation tensions than does the compound from which it is formed. There is, of course, one temperature, that of the co-existence of the two sulphates and the oxide, at which the dissociation tensions of the two are equal.

It follows from the above that, if a metal sulphate is held at constant temperature in a space wherein the sulphur trioxide concentration is less than the equilibrium concentration corresponding to the prevailing temperature, the sulphate will undergo dissociation. If the sulphur trioxide concentration is kept constant, the dissociation will continue either until the sulphate is completely converted into oxide or is converted into a basic compound, the dissociation tension of which is less than the prevailing partial pressure of sulphur trioxide.

In case the formation of a basic sulphate is possible and the normal sulphate is held at constant temperature in a space containing a lower sulphur trioxide concentration than corresponds to the dissociation tension of the basic sulphate, the normal compound will first dissociate until it has been converted into the basic sulphate, which in turn will dissociate with the production of perhaps a second basic compound, or more commonly the metal oxide. On the other hand, if a metal oxide is held at constant temperature in a space wherein is maintained a higher concentration of sulphur trioxide than corresponds to the dissociation tension of the sulphate at the prevailing temperature, the oxide will be sulphatized, the normal sulphate being produced directly from the oxide only when basic sulphates do not exist. When basic sulphates are possible, the process of forming the normal compound will be the reverse of the process of its decomposition, as described above.

The view may be maintained that such considerations as have been outlined above are of no practical value in a study of the reactions of roasting, because in the roasting furnace the gases are drawn off continuously and with such rapidity that the sulphur trioxide concentration is maintained at an extremely low figure. Numerous analyses of roasting furnace gases appear to support this contention. The fact remains, however, that sulphates are formed during the roasting of sulphide ores, and that in many cases they are subsequently decomposed. In view of this, what are the reactions and what considerations do apply, if the foregoing do not?

The fallacy of such arguments doubtless lies in the

¹ Hofman, General Metallurgy, p. 403, 1913. Friedrich, Metallurgie, VI, 170, 1909.

² Nernst, Theoretical Chemistry, Translation 6th Ger. Ed., p. 676.

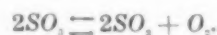
assumption that the concentration of sulphur trioxide in the furnace gas as a whole is the same as that in the gas immediately in contact with the roasting ore. Such is not the case. The concentrations of sulphur oxides in the gas in contact with even the topmost layer of grains in a roasting bed of ore are probably higher than in the furnace gas as a whole, owing to absorption and to the rate of diffusion of these compounds through the film of gas in contact with the solids. Laying aside this point for the present, it cannot be denied that the gas in the interstices of the ore bed is usually much richer in sulphur oxides and poorer in oxygen than is the furnace gas or the flue gas. Otherwise rabbling or stirring the roasting ore would serve no useful purpose, while in fact rabbling does accelerate the process of roasting by exposing new particles of ore to the direct action of the furnace gas, by liberating the sulphur oxides from the interstices of the ore bed, and by thus increasing the oxygen concentration within these spaces.

Inasmuch as it is the sulphur trioxide concentration in the gas in close contact with the roasting ore and not its concentration at some distance away that constitutes a determining factor in the formation and dissociation of metal sulphates, it becomes evident that, in the consideration of these reactions, attention must be directed toward the composition of the interstitial gas and toward the reactions occurring in such spaces rather than toward the composition of the furnace gas as a whole. But it must be remembered that thoroughness and rapidity of stirring or rabbling together with the depth of the bed of ore being worked constitute important factors in determining the average differences in composition that may exist between the interstitial gas and the furnace gas.

The formation and decomposition of a metal sulphate according to the reversible processes described in a preceding paragraph is in many respects similar to the formation and dissociation of calcium carbonate, according to the reaction,



In the case of the sulphate the process is not quite so simple and does not lend itself so readily to investigation, because of the complication arising from the dissociation of the sulphur trioxide according to the reaction,



The reaction is reversible as is shown by the equation. It is endothermic when proceeding from left to right, which indicates that increasing temperature produces a change in the equilibrium that causes, under given conditions, a more complete dissociation of the sulphur trioxide.

Since at the elevated temperatures of the roasting furnace the reactions of sulphate formation and decomposition occur in company with the reversible reaction between the sulphur oxides and oxygen, the two processes are inseparably linked, and the former cannot be well understood without a clear understanding of the latter. Therefore a discussion of the sulphur trioxide, sulphur dioxide, and oxygen equilibrium will be presented.

The most useful information in regard to this reaction is obtained from the law of chemical mass action, which states that at a definite temperature equilibrium among the three gases is defined by the equation,

$$\frac{C_{\text{SO}_2} C_{\text{O}_2}}{C_{\text{SO}_3}} = K$$

Wherein C_{SO_2} , C_{O_2} and C_{SO_3} are the concentrations of the gases designated by the subscripts, and K is the reaction constant. The value of K , while constant for each temperature, increases with increasing temperature.

This, it will be noted, indicates under given conditions a decrease in the concentration of sulphur trioxide in the equilibrium mixture as the temperature increases.

The determination of the values of the equilibrium constant of this reaction has been the object of a number of investigations,² and, while the results of the various observers are somewhat conflicting, it appears that those of Bodenstein and Pohl are perhaps the most reliable. Accordingly their figures will be quoted, and used in certain calculations that are to follow. Table I contains the values of K determined by these investigators.

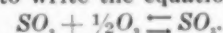
TABLE I—EQUILIBRIUM CONSTANTS OF SO_2 , SO_3 , AND O_2 REACTION AT VARIOUS TEMPERATURES

Temp. C.	K	Log K
528°	1.55×10^{-4}	-4.810
579	7.55×10^{-5}	-4.126
627	3.16×10^{-5}	-3.500
680	1.12×10^{-5}	-2.914
727	3.54×10^{-6}	-2.451
789	1.26×10^{-6}	-1.900
832	2.80×10^{-7}	-1.552
879	8.16×10^{-8}	-1.089

The values of K given in the above table apply to the reaction,



and, in order to use these values in calculations, it is necessary to use the concentrations of the gases expressed in gram molecules per liter. It happens that calculations of the kind that are to be made are more conveniently performed and the results are more readily interpreted, when the partial pressures of the gases are used in place of the concentrations. Also it will be more convenient to write the equation in the form,



The conventional mass action equation for the reaction, when so expressed and when the partial pressures of the gases are being considered, is

$$\frac{p_{\text{SO}_3}}{p_{\text{SO}_2} \sqrt{p_{\text{O}_2}}} = K_1$$

Wherein K_1 is the mass action constant, the subscript being employed to distinguish it from the K used above.

Calculation of the values of K_1 from those of K is accomplished with the aid of the gas law equation,

$$pv = NRT$$

Wherein p is the pressure of the gas under consideration; v is its volume; N is the number of gram molecules or mols involved; R is the gas constant; and T is the absolute temperature.

Now the concentration, C , of any gas expressed in mols per liter is N/v , N being the number of mols involved and v being the volume of the gas in liters under the assumed conditions.

Hence the gas-law equation may be expressed in the form,

$$p = CRT, \text{ or } C = \frac{p}{RT}$$

Substituting for the concentrations, C_{SO_2} , C_{O_2} and C_{SO_3} in the first mass-law equation their equivalents, p_{SO_2}/RT , etc., there is obtained the equation,

$$\frac{p_{\text{SO}_2}^2 p_{\text{O}_2}}{p_{\text{SO}_3}^2} \cdot \frac{1}{RT} = K, \text{ or } \frac{p_{\text{SO}_2}^2 p_{\text{O}_2}}{p_{\text{SO}_3}^2} = RTK$$

Extracting the square root of the last expression and inverting both sides gives

$$\frac{p_{\text{SO}_3}}{p_{\text{SO}_2} \sqrt{p_{\text{O}_2}}} = \frac{1}{(RTK)^{1/2}}$$

² Knietzsch, *Berichte d. Deut. Chem. Ges.*, XXIV, 4069, 1901. Mineral Industry, X, 622, 1901. Bodländer and Koppen, *Zeit. für Elektrochem.*, IX, 787, 1903. Bodenstein and Pohl, *Zeit. für Elektrochem.*, XI, 373, 1905. Von Lucas, *Zeit. für Elektrochem.*, XI, 457, 1905.

Combining this with the second mass-law equation involving K_1 yields the relation,

$$K_1 = \frac{1}{(RTK)^{\frac{1}{2}}}$$

The value of R to be used depends upon the unit in which it is desired to express the gas pressures. If these are to be expressed in millimeters of mercury, $R = 62.4$, and the expression relating K and K_1 becomes

$$K = \frac{1}{(62.4 TK)^{\frac{1}{2}}}$$

The temperature, T , is expressed in degrees, C , on the absolute scale.

With the aid of the above equation, Table II, containing values of K_1 and $\log K_1$, has been prepared. Plotting

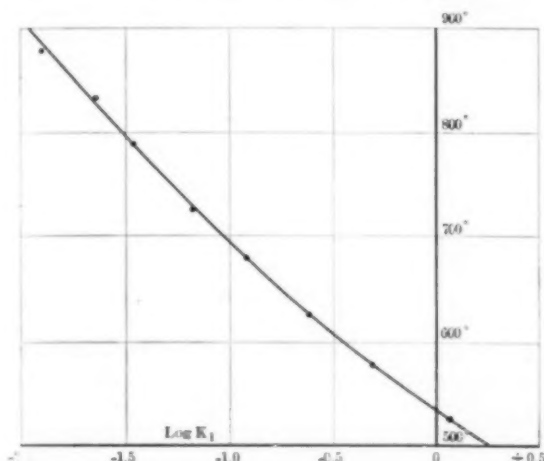


FIG. 1—VARIATION OF $\log K_1$ WITH TEMPERATURE

these values of $\log K_1$ against their corresponding temperatures gives Fig. 1. From this the values of $\log K_1$ and K_1 at intervals of 50 deg., beginning at 500 deg., are taken to form Table III.

TABLE II—VALUES OF K_1 AND $\log K_1$ AT VARIOUS TEMPERATURES

Temp. C.	K_1	$\log K_1$
528°	1.14	0.057
579	4.96×10^{-1}	-0.304
627	2.39×10^{-1}	-0.622
680	1.22×10^{-1}	-0.913
727	6.70×10^{-2}	-1.174
789	3.46×10^{-2}	-1.461
832	2.27×10^{-2}	-1.644
879	1.29×10^{-2}	-1.890

TABLE III—VALUES OF K_1 AND $\log K_1$ AT 50° INTERVALS BEGINNING WITH 500°

Temp. C.	K_1	$\log K_1$
500°	1.78	0.250
550	7.95×10^{-1}	-0.100
600	3.55×10^{-1}	-0.450
650	1.78×10^{-1}	-0.750
700	9.23×10^{-2}	-1.035
750	5.13×10^{-2}	-1.290
800	3.06×10^{-2}	-1.515
850	1.82×10^{-2}	-1.740
900	1.10×10^{-2}	-1.960

By substituting the proper value of K_1 in the mass-law equation and by using this in connection with the chemical equation, it is possible to calculate with reasonable certainty the composition of the equilibrium mixture that will result from bringing together specified amounts of sulphur trioxide, sulphur dioxide, and oxygen at a definite temperature and pressure.

A special case that, as will be subsequently shown, is of particular interest in connection with the formation and decomposition of sulphates, is when sulphur trioxide alone is decomposed, or when sulphur trioxide

is formed by bringing together sulphur dioxide and oxygen in the proportions of two mols of the former to one of the latter. Starting with pure sulphur trioxide it is seen from the chemical equation that at equilibrium as many mols of sulphur dioxide have been formed as of sulphur trioxide decomposed, and half as many mols of oxygen have been produced as of sulphur dioxide. Consequently, in the equilibrium mixture the conditions are represented by the following equations:

$$\frac{p_{SO_2}}{p_{SO_3} p_{O_2}^{\frac{1}{2}}} = K_1$$

$$p_{SO_2} = 2p_{O_2}$$

$$p_{SO_3} + p_{SO_2} + p_{O_2} = p_t$$

Wherein p_{SO_3} , p_{SO_2} and p_{O_2} are the partial pressures of sulphur trioxide, sulphur dioxide and oxygen, respectively; and p_t is the total pressure of these three gases. Eliminating p_{SO_2} and p_{O_2} from these equations yields a relation involving the partial pressure of sulphur trioxide in terms of K_1 and the total pressure, p_t .

$$\frac{p_{SO_3}}{(p_t - p_{SO_3})^{\frac{3}{2}}} = 0.385 K_1$$

This equation is useful in calculating the partial pressure of sulphur trioxide in the equilibrium mixture resulting from the dissociation of this compound under given conditions of temperature and total pressure. The solution of the equation for p_{SO_3} is most readily accomplished by trial.

The composition of equilibrium mixtures resulting

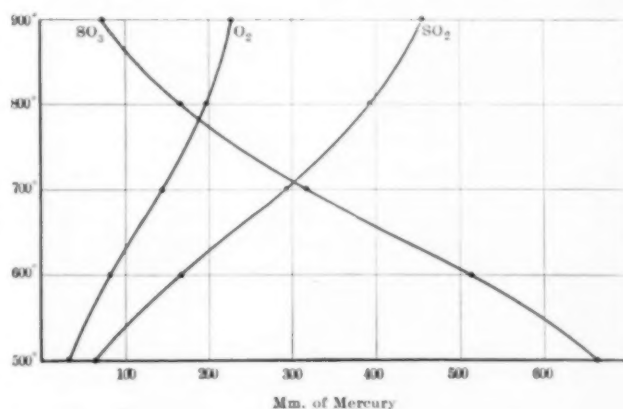


FIG. 2—COMPOSITION OF SO_3 , SO_2 AND O_2 EQUILIBRIUM MIXTURES RESULTING FROM DISSOCIATION OF SO_3 AT ATMOSPHERIC PRESSURE

from the dissociation of sulphur trioxide at various temperatures under a pressure of one atmosphere (760 mm. of mercury) have been calculated. They are given in Table IV, and are shown graphically in Fig. 2.

TABLE IV—COMPOSITION OF EQUILIBRIUM MIXTURES OF SO_3 , SO_2 AND O_2 EXPRESSED IN MM. OF MERCURY, THE TOTAL PRESSURE BEING 760 MM.

Temp. C.	P_{SO_3}	P_{SO_2}	P_{O_2}	$\frac{P_{SO_3}}{P_{SO_2}}$
500°	663	65	32	10.2
600	517	162	81	3.19
700	322	292	146	1.11
800	170	393	197	0.433
900	75	457	228	0.164

An important point to be considered in connection with the reaction under discussion is that of reaction velocity, which determines the length of time required for a mixture of the gases to react and produce equilibrium conditions. The time required depends, of course, upon the original concentrations of the reactants and upon the temperature. The effect of temperature in this case, as in most others of its kind, is to accel-

erate the reaction rate at the higher temperatures. But aside from these factors there is another of even greater importance, namely, the effect of catalysts upon the reaction rate. It has been found that under given conditions of temperature, initial gas mixture, etc., the reaction will proceed to equilibrium conditions at a greatly accelerated rate when the gases are brought into contact with such substances as platinized asbestos, and that various metal oxides, notably ferric oxide, affect the reaction velocity in a similar manner but to a lesser degree.* The catalyst does not alter the conditions of equilibrium, these being determined by the temperature and the partial pressures of the reacting substances; and in general the catalyst has an equal effect upon the reaction velocity, whether the direction of the reaction happens to be toward the formation of sulphur trioxide or toward its decomposition.

To return to the question of the metal sulphates, numerous investigations have been conducted to determine the conditions under which the common sulphates are formed and decomposed in the roasting furnace. An interesting and instructive piece of work is that of Wöhler, Plüddemann and Wöhler,⁵ who determined the equilibrium conditions of several sulphates over considerable ranges of temperature. Their method consisted of heating the sulphate in an evacuated tube at constant temperature and measuring with a mercury manometer the maximum pressure of the gases evolved. Platinum sponge was placed above the sulphate to insure the rapid attainment of equilibrium conditions within the heated space. Hence the pressure measured was that due to the equilibrium mixture resulting from the dissociation of the sulphur trioxide evolved by the sulphate. The partial pressure of the sulphur trioxide in this mixture represents the dissociation tension of the sulphate at the prevailing temperature. The total pressures of the sulphur oxides and oxygen at various temperatures above the sulphates of metallurgical interest that were studied in the Wöhler-Plüddemann experiments are collected in Table V. These data have been plotted to scale in Fig. 3.

TABLE V—TOTAL PRESSURES OF SO₂, SO₃, AND O₂ ABOVE SULPHATES

Fe ₂ (SO ₄) ₃		Al ₂ (SO ₄) ₃		CuSO ₄		2CuO·SO ₃		ZnSO ₄	
Temp. Deg. C.	Press. Mm.	Temp. Deg. C.	Press. Mm.	Temp. Deg. C.	Press. Mm.	Temp. Deg. C.	Press. Mm.	Temp. Deg. C.	Press. Mm.
553	23	572	28	546	43	600	62	675	5
570	33	621	51	588	55	653	98	690	6
592	45	681	120	615	70	686	123	720	24
614	70	702	180	642	98	705	139	750	61
634	113	720	261	665	130	728	173	775	112
650	149	731	356	700	233	745	209	800	189
660	182	742	480	714	324	775	298	.....	.....
680	286	748	692	725	460	805	542	.....	.....
690	401	.....	.....	731	647	.....	.....	.....	.....
699	560	.....	.....	.....	.....	.....	.....	.....	.....
707	715	.....	.....	.....	.....	.....	.....	.....	.....

From the foregoing figures the equilibrium pressures of sulphur trioxide corresponding to various temperatures may be calculated for each of the sulphates listed by means of the equation,

$$\frac{p_{\text{SO}_2}}{(p_t - p_{\text{SO}_2})^{2/3}} = 0.385 K_1.$$

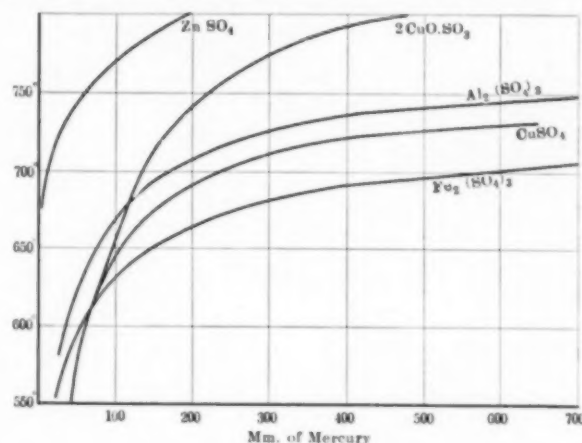
For example, at 650 deg. the total equilibrium pressure of the sulphur oxides and oxygen above copper sulphate is seen to be 105 mm. See Fig. 3. Substituting 105 for p_t in the above equation and substituting for K_1 its value as given in Table III yields the relation,

$$\frac{p_{\text{SO}_2}}{(105 - p_{\text{SO}_2})^{2/3}} = 0.385 \times 0.178.$$

* Knietzsch, loc. cit.

⁵ Ber. der Deut. Chem. Ges., XLI, pt. 1, p. 703, 1908.

Solving this equation by trial shows p_{SO_2} to be 37.7 mm. By this method the equilibrium pressures of sulphur trioxide above the different sulphates have been calculated for various temperatures. The calculated values are given in Table VI, and they have been plotted against the corresponding temperatures in Fig. 4.

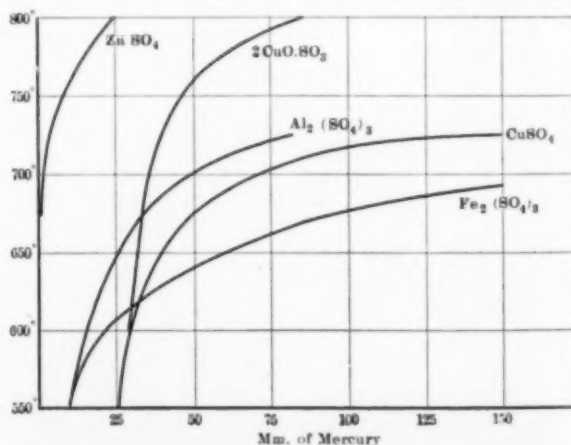
FIG. 3—TOTAL EQUILIBRIUM PRESSURES OF SO₂, SO₃, AND O₂ ABOVE VARIOUS SULPHATES

There are thus provided in convenient form the known facts concerning the equilibrium of a few of the metal sulphates and oxides with sulphur trioxide. It is unfortunate indeed that other sulphates have not been

TABLE VI—DISSOCIATION TENSIONS OF SULPHATES AT VARIOUS TEMPERATURES, EXPRESSED IN MM. OF MERCURY

Temp. Deg. C.	Fe ₂ (SO ₄) ₃	CuSO ₄	Al ₂ (SO ₄) ₃	2CuO·SO ₃	ZnSO ₄
550	9.8	25.5	9.8	.....	.....
600	22.8	28.7	16.0	27.6	.....
650	58.0	37.7	25.8	33.0	.....
675	94.0	50.5	34.0	.....	0.5
700	219.	71.0	50.0	36.0	0.8
725	.....	148.	82.0	39.0	.....
750	.....	.....	.....	46.0	7.5
775	.....	.....	.....	.....	14.5
800	.....	.....	.....	55.0	24.0

studied in a similar manner, but the data thus provided are useful in indicating the general relationship be-

FIG. 4—DISSOCIATION TENSIONS OF VARIOUS SULPHATES WITH RESPECT TO SO₂

tween temperature and the pressures of sulphur trioxide necessary to effect the formation of sulphates or to allow their decomposition.

In general, the shape of each curve shows at first a slow increase of dissociation tension as the temperature increases. Then the increase in dissociation tension

with temperature becomes more marked, and finally a comparatively slight change in temperature produces a very great change in the dissociation tension. The question of the order of decomposition of a mixture of metal sulphates is seen to depend somewhat upon the sulphur trioxide pressure in contact with them, the order at low pressures being in some cases reversed from that at higher pressures, as is shown by the crossing of the dissociation tension lines on the diagram, Fig. 4.

The properties of ferric sulphate, as shown by the curve representing its dissociation tension, deserve special mention. It will be noted that the dissociation tension of this compound is low at the lower temperatures shown on the diagram, but increases more rapidly with increasing temperature than is the case with the other sulphates shown. Since in the roasting furnace pyrite is one of the first sulphides to be ignited and oxydized, ferric oxide or the magnetic oxide of iron is produced at comparatively low temperatures. Owing to the low dissociation tension of ferric sulphate at low temperatures, it is to be expected under the circumstances that this sulphate will be the first to form. With increasing temperature, however, the dissociation tension of the ferric sulphate increases much more rapidly than that of the other sulphates. Consequently, although it may be the first to be formed, the ferric sulphate will in general suffer decomposition at lower temperatures than the other sulphates.

In viewing the subject of sulphate formation and decomposition from the standpoint of the equilibrium conditions of the reactions it must be remembered that it is very difficult, if not impossible, to predict or even to determine the magnitude of the sulphur trioxide concentration in contact with the ore at any time. This much, however, can be said: The concentrations of the sulphur oxides in the gas in immediate contact with the ore and in the interstices of the ore bed are greater than is shown by the analysis of the furnace gas as a whole. Also the composition of the gas in the interstices approaches that of the furnace gas as the depth of ore bed decreases and as the rapidity of rabbling increases.

From the foregoing discussion it follows that the formation of sulphates in the roasting furnace is promoted by low temperature, thick beds of ore, and slow rabbling; and that the reverse conditions will in general prevent the formation of sulphates or at least assist in their decomposition once they are formed. In particular it should be noted that a sulphate does not have a definite temperature of formation or of decomposition any more than water has a definite boiling point, the one being as dependent upon the sulphur trioxide concentration in the space surrounding the sulphate as the other is dependent upon the atmospheric pressure above the water.

Another important and useful investigation of the properties of the metal sulphates is that of Hofman and Wanjukow.⁷ In their experiments a small amount of the sulphate contained in a porcelain boat was introduced into the horizontal tube of an electrically heated furnace, through which was passed a current of dry air. The temperature of the furnace and its contents was gradually raised, and observations were made to determine the temperature at which the sulphate begins to dissociate. In this manner the sulphate is subjected to conditions that resemble to a certain extent those obtaining in the roasting furnace.

Since in these experiments only small amounts of the sulphate (usually 0.3 g. of the crystalline salt) were worked with, the depth of the layer of sulphate in the boat was slight. With a fairly rapid current of air through the tube the partial pressure of the sulphur

trioxide in contact with the surface grains of the sulphate was maintained at a low figure; though the same cannot be said of the conditions surrounding the grains of the lower layers. It is to be expected, however, that under the conditions described signs of decomposition of the sulphates will become evident at temperatures corresponding to low dissociation tensions. That this is in general the case may be seen by comparing the figures of Table VII with the curves of Fig. 4.

TABLE VII—DESULPHATIZATION OF ANHYDROUS METAL SULPHATES—HOFMAN AND WANJUKOW

Metallic Sulphates	Temperature of Beginning of Decomposition, Degrees C.	Temperature of Energetic Decomposition, Degrees C.	Products of Decomposition	Remarks
FeSO ₄	167	480	Fe ₂ O ₃ ·2SO ₂	Yellow-brown
Fe ₂ O ₃ ·2SO ₃	492	560	Fe ₂ O ₃	Red
Bi ₂ (SO ₄) ₃	570	639	5Bi ₂ O ₃ ·4(SO ₂) ₃	White
Al ₂ (SO ₄) ₃	590	639	Al ₂ O ₃	White
PbSO ₄	637	705	6PbO·5SO ₃	White
CuSO ₄	653	670	2CuO·SO ₃	Orange-color
MnSO ₄	699	790	Mn ₂ O ₃	Dark red to black
ZnSO ₄	702	720	3ZnO·2SO ₃	White, cold and not.
2CuO·SO ₃	702	736	CuO	Black
NiSO ₄	702	764	NiO	Brownish green
CoSO ₄	720	770	CoO	Brown to black
3ZnO·2SO ₃	755	767	ZnO	Hot yellow, cold white
CdSO ₄	827	846	5CdO·SO ₄	White
5Bi ₂ O ₃ ·4(SO ₂) ₃	870	890	Bi ₂ O ₃ (?)	Yellow
5CdO·SO ₄	878	890	CdO	Black
MgSO ₄	890	972	MgO	White
Ag ₂ SO ₄	917	925	Ag	Silver white
6PbO·5SO ₃	952	962	2PbO·SO ₃ (?)	White to yellow
CaSO ₄	1,200		CaO	White
BaSO ₄	1,510		BaO	White

In determining the temperatures specified above the investigators obtained evidence of decomposition in the following manner: The furnace containing the sulphate under investigation was heated slowly by passing an electric current of constant strength through the resistance coil. Data for a temperature-time heating curve of the furnace were obtained by making temperature observations at definite time intervals, the position of the junction of the thermo couple, with which the observations were made, being near the surface of the sulphate contained in the boat. Since the dissociation of a sulphate is an endothermic reaction, the curve plotted from such data will show a jog when the rate of decomposition of the compound becomes sufficient to make evident the thermal effect in this manner. Also the gases issuing from the furnace tube were tested by suitable indicators for sulphur trioxide and sulphur dioxide.

The figures given in Table VII represent, therefore, simply the temperatures at which decomposition under the existing conditions could be identified by the means employed. In fact, in many cases, due to slight evidences of dissociation at lower temperatures than those specified, considerable latitude was left to the observer in his decision as to just what temperature corresponds to the beginning of decomposition at a practically important rate. Consequently the figures given, while of great value because they represent temperatures at which the various sulphates are decomposed at a fairly uniform rate under certain conditions determined by the method of the experiments, do not necessarily represent the minimum temperatures at which the sulphates undergo decomposition. Nor do these figures necessarily represent the temperatures at which the respective sulphates are decomposed in the roasting furnace, the temperature of decomposition being in each case a variable as has been explained in a preceding paragraph.

To summarize, it may be said that the decomposition temperatures thus determined are dependent to a great extent upon the rates of decomposition of the different sulphates under the conditions existing at the time of the experiments. This brings up the question of reaction velocity in heterogeneous systems and the factors and conditions upon which it depends. These are of im-

⁷ T. A. I. M. E., XLIII, 523, 1913.

portance, because, from a practical viewpoint, it is of little use to know that a reaction may take place but at so slow a rate as to render its effects imperceptible.

Metallurgical Smoke

The U. S. Bureau of Mines has recently issued *Bulletin* 84, by Charles H. Fulton, setting forth in "plain and simple English" the facts regarding metallurgical smoke and its treatment. The pamphlet contains much valuable information, including data on operating plants and illustrations of various methods for controlling smoke production.

As showing the tremendous volume of smoke that may be produced at a large smelter, the following data

TABLE I—PART OF FLUE SYSTEM

Constituent	Flue from roasting furnaces	Flue from blast furnaces	Flue from converters	Flue from reverberatory furnaces	Flue at base of stack
Sulphur dioxide	2.545	1.274	2.845	4.423	1.164
Sulphur trioxide	0.275	0.086	0.0505	0.0044	0.0395
Carbon dioxide	0.1136	6.493	0.2084	5.242	2.748
Water vapor...	2.784	3.490	1.061	3.869	2.834
Arsenic trioxide	0.0073	0.0091	0.00073	0.0156	0.00465
Oxygen	14.02	10.18	12.04	10.37	11.88
Nitrogen	81.18	78.13	83.64	79.57	80.73
Carbon monoxide	None	None	None	Trace	None
Total	100.90	99.70	99.80	99.50	99.40

are given on the Anaconda smelter. The stack discharges 1,341,000,000 cu. ft. of smoke per 24 hours, containing about 1.734 per cent by volume of sulphur dioxide, equivalent to 3427 tons of sulphuric acid.

The composition of gases from a typical Western copper smelter, in percentage of volume at 0 deg. Cent. and 760 mm pressure, is given as follows:

The dust and fume losses at smelting plants reaches a magnitude that would not be suspected unless thoroughly investigated. Thus at Great Falls with the old flue system in use it was demonstrated that there was a daily loss in dust of 3775 lb. copper, 106 oz. silver and 9.71 oz. gold. With the new flue system this was reduced to 347 lb. copper, 28.5 oz. silver

and 0.2 oz. gold. The saving effected was \$372 a day by a flue system that cost \$1,100,000. At the Copper Queen plant there was a daily loss of copper in dust amounting to between 6000 and 18,000 lb. copper, depending on the number of furnaces in use.

The *Bulletin* discusses methods of recovering fume and dust from smelter smoke, and describes and illustrates different flue systems, bag houses and electrical precipitation apparatus. It also covers the manufacture of sulphuric acid from smelter gases and describes the work at the Tennessee smelters. The Hall and Thiogen processes for recovering sulphur from roasting ores are briefly described.

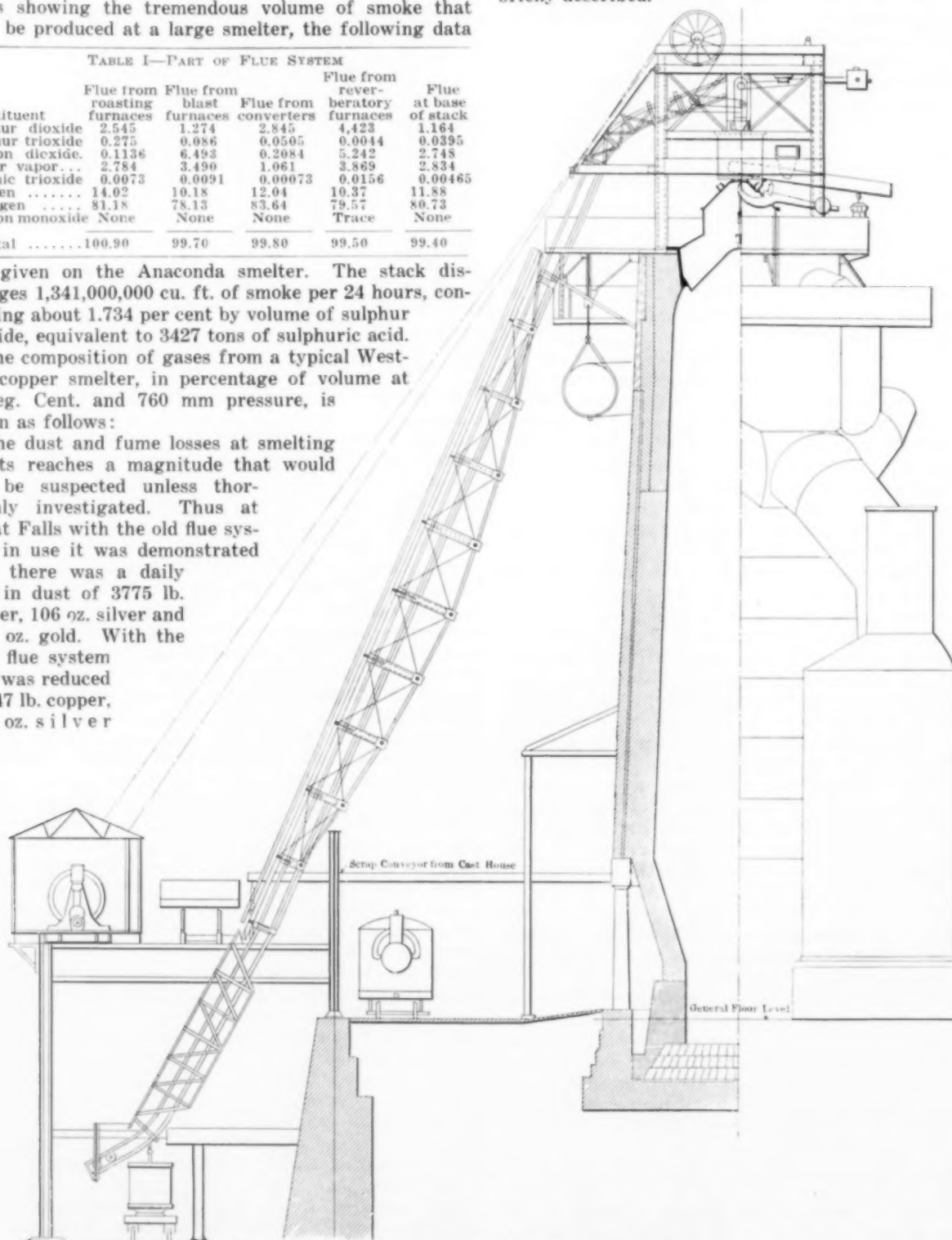


FIG. 22—GENERAL ARRANGEMENT OF NEELAND TOP

Filling the Blast Furnace

BY J. E. JOHNSON, JR.

(Concluded from page 173)

The Bucket System of Distribution

When the Duquesne furnaces were designed, as I have previously explained, practically all the traditions of blast furnace design were discarded and the engineers struck out on lines boldly new in almost every direction. This was true in regard to the filling system which was invented for that plant by M. A. Neeland, then chief engineer of those works.

When the plans for the plant were started there were only two mechanically filled furnaces running, one with the Brown top at Sharon, previously mentioned, and one with the upper hopper closed by an orange peel at the Lucy furnaces which their superintendent recommended be not adopted.

A set of drawings for a skip-filling system had been made, but when Mr. Rotoff (since deceased) came to the plant to be superintendent of the furnaces which it was proposed to build, he rejected this design absolutely as he had had experience with some very unsuccessful skip-filled furnaces at the Isabella plant where the segregation of the lumps and fine had manifested itself very clearly and had demonstrated how completely it could prevent the satisfactory working of the furnace.

The top now to be described was designed by Mr. Neeland to overcome this difficulty, and it has been very successful in doing so. To accomplish this result he decided to use a type of bucket for hoisting the material which could be accurately centered on the furnace top before dumping, and then be dumped uniformly in all directions.

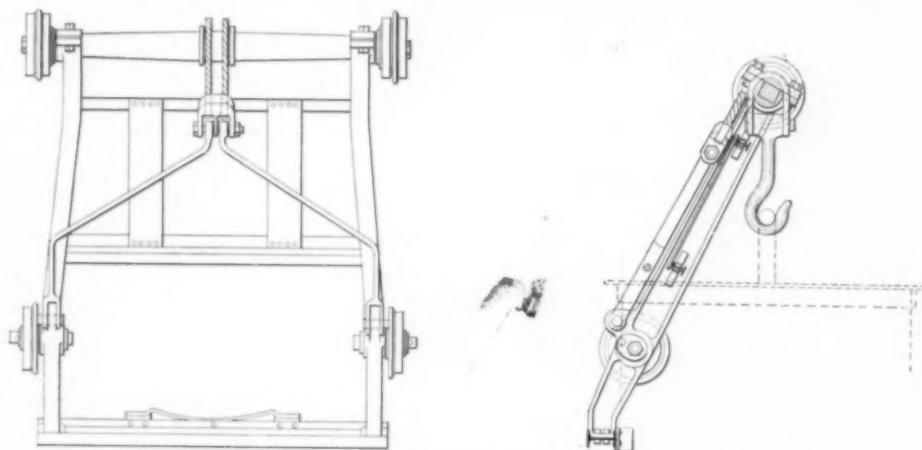
The huge bucket used has its bottom closed by a bell by the central rod of which the whole is suspended from the truck which ran on the inclined hoist. The general arrangement is shown by Fig. 22 (p. 226).

The scale cars on which the buckets are set run along under the double row of bins from which the buckets are charged with the required material. Each bucket in turn is then brought into the central plane of the skip where it is picked up by the hook on the inclined truck (Figs. 23 and 24) and carried to the top of the furnace. There the front end of the truck with the bucket hanging to it enters a vertical slide in the center line of the furnace top and is lowered vertically to a seat on the top of the gas seal. The further downward movement of the slide lets the bell bottom of the bucket pass down inside the gas seal carrying the counterweighted gas seal bell with it. The bucket then discharges and the return movement of the slide raises the bell-bottom of the bucket back to place, allows the gas seal to be sealed by its counterweight, and finally picks up the bucket itself on its own bell, and the return trip of the truck takes it back to the bottom where it is unhooked and another loaded bucket picked up. The arrangement is well shown by Figs. 25 and 26 which show the bucket resting on its seat in the furnace top and its bell on top of the gas seal bell.

It will be seen that there is no horizontal velocity

whatever to the stock, and that if it is reasonably level in the bucket an equal amount is discharged on each sector of the bell. It is, in fact, as if the hopper of the double bell top were filled under the bins brought up to the top of the furnace and dumped, instead of being filled by the intervention of the skips. It is worthy of note that the bins are arranged in parallel rows on each side of the scale car tracks so that the buckets are filled alternately from opposite sides thus balancing up the irregularity which would have arisen from the great segregation on one side of the bucket had it been filled always from one side. At the same time it is no more than fair to add that Mr. Neeland had this matter of segregation very much in mind and he designed the bins with the shortest possible chutes to give a low delivery velocity and so arranged that the stream of material strikes as closely as possible on the apex of the bell bottom of the buckets.

In more recent years this system of filling has been improved by the addition of a motor on the scale truck which rotates the buckets either through a certain defi-



FIGS. 23 AND 24—BUCKET CARRIAGE OF THE NEELAND TOP

nite angle after they have been filled, increasing by a fixed amount for each bucketful, as for instance 90, 180 and 270 deg., or else the buckets are rotated continuously while charging, so that the charge may be distributed in uniform rings thus securing an equable distribution of lumps and fines in every portion.

Ford-Parkes Top

Various modifications of this type of filling system have been made. A general drawing of the Ford-Parkes design was shown in the second article of this series. The details of the top and bottom are shown by Figs. 27, 28, 29 and 30. The buckets in this design are not delivered onto a scale car, but onto a turntable carrying four bucket seats. This table is rotated 90 deg. at a time, and this rotation takes the empty bucket away and brings a freshly filled one to take its place. When the bucket is at 180 deg. from the position under the skipway, it is filled from the scale car which in this case is the regular hopper type of scale car. The general arrangement of the turntable and the motor for turning it are also clearly shown, also the scale car in position in Fig. 28.

The general design of the bucket-carrying truck is shown at the foot of the incline, the large quadrant at the front or upper end of the truck from which the pick-up hook hangs is clearly shown. This quadrant is rigidly attached to the rear wheel of the truck and pivoted on its own center in the center of the equalizer between the two front pairs of wheels. It is evident that if the rear wheel of the truck be swung up around the pivot as a center, that the hook carried by the chain

unwinding from the quadrant will move vertically downward.

Referring now to Fig. 30, showing the top of the incline, there will be seen the convex curve on which the two front pairs of wheels of the truck run, and above a guiding slot with a sharp reverse curve which acts as a guide for the rear pair of wheels. The upper portion of this guide is a circle struck from the center of the truck in its top position, and this circle permits the rear wheels of the truck to rise while holding the pivot of the quadrant rigidly in its place, and gives the required vertical movement to the bucket as a whole. This seats the bucket on top of the gas seal exactly as is done with the Duquesne top, but without the assistance of the vertical slide, and therefore somewhat more

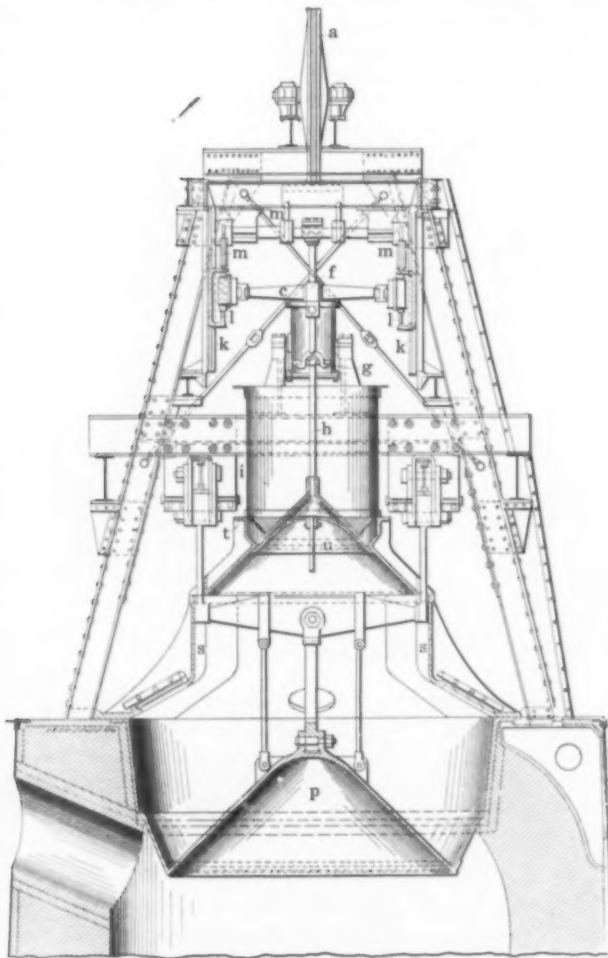


FIG. 25—DETAILS OF NEELAND TOP

simply. The return of the rear wheels to their normal position is secured by a heavy counterweight which the rear wheels pick up just before they enter the guide, and which pulls them back down on to the incline as soon as the hoisting rope is slackened. The head-shieve is clearly shown just above the curved guide.

Other modifications of this type of top have been built but the principle is no different from those illustrated in any of them.

At one of the most successful plants in the country the bucket is never unhooked from the carriage but rigidly attached to it just as the skip is attached to the hoisting rope, but provision is made for rotating the skip on its vertical axis to each of three equally spaced directions in turn, this eliminating irregularities in the charging of the skip.

It will be seen that this type of filling gives precisely the same type of distribution as the double-bell type of

top, and with almost the same limitations. That is to say, irregularities due to the way in which the charge is delivered into them may and generally do occur with either type of filling, and may be more or less completely compensated by the correct rotation of the receiving part to the different dumping points in regular order.

At the same time it must be recognized that the advantage is with the bucket system if the top be not rotated because of the smaller number and lower velocity of transfers of the stock with corresponding reduction of the opportunity for segregation.

Guiding the Bell Movement

One point of extreme practical importance in all types of furnace tops is the path of the main bell in its descent. It is obvious that if it be attached directly to the end of the bell lever the latter swinging as it does in the arc of a vertical circle will carry the bell in a similar path and it will be either one side or the other of the center of the furnace, in the plane of its motion, practically all

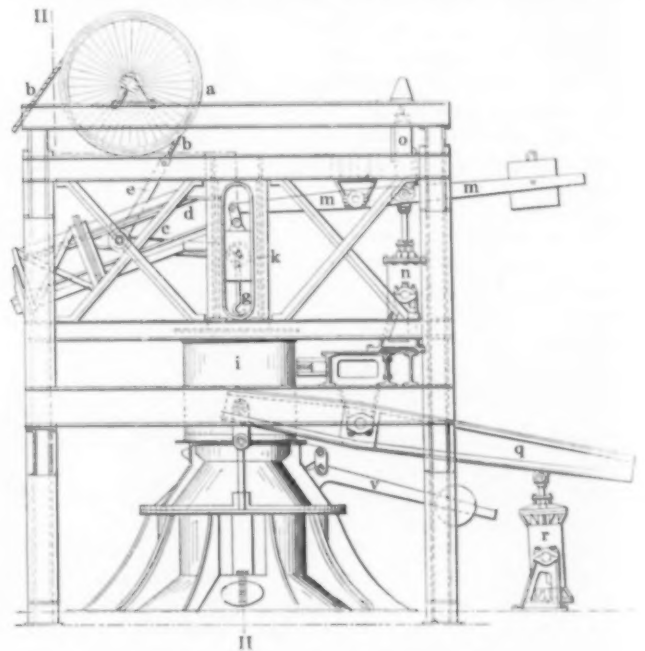


FIG. 26—DETAILS OF NEELAND TOP

the time. The projecting end of the bell lever is quite long, and it looks as though the curvature of the path described by it could be ignored, but this is by no means the case. The versed sine of the arc described always amounts to a couple of inches and may easily exceed this, which is enough to insure there being a considerably greater portion of the charge on one side of the furnace than on the other, and much bad furnace work has been attributable to this irregularity. The path of the bell rod must always be a straight line exactly in the center of the furnace. This straight line can be produced either by a rigid guide for the bell rod, connecting the latter to the lever with a short link; a quadrant from which a flexible suspension member unwraps always in a vertical line as the lever rises and falls, or a mechanical parallel motion similar to that of Watt's steam engine. A good illustration of the quadrant system is shown in Fig. 10, in which the bell is suspended from the triangles which are hung from chains working in grooves in the castings on the ends of the bell lever, these being segments of circles concentric with the center of the lever.

The parallel motion design is well shown by Fig. 12. The bell rod is not connected directly to the end of the

main bell lever but to a short link which projects above it, the upper end of which is guided by a connecting link pivoted to a projection on the fulcrum of the main bell lever. The proportions are such that the bottom point of the suspension link where it is attached to the bell rod moves in an absolutely straight line. In Fig. 12 the small bell is guided by the main bell rod and therefore is not provided with any parallel motion, only with a suspension link to connect the curved movement of the bell lever with the straight-line movement of the bell rod. But in many cases the lever of the small bell is provided with its own parallel motion also. The rigid guide is used on the Baker top, the (two) bell rods passing through guide castings riveted to the gas seal and others on the superstructure at the upper end of

nance, which is necessary in order to prevent gas explosions.

In the other method of operating, the counterweight is dispensed with and the direct downward pull of the cylinder keeps the bell closed. This is somewhat simpler than the other method or at least permits doing away with the counterweight; moreover by operating in this way the cylinder can be placed at or near the bottom of the furnace and connected with the bell by means of a wire rope, but obviously this cannot be done when the bell is kept shut by a counterweight. However, a counterweight can be applied at the bottom of the rope and immediately over the top of the cylinder if desired.

In some cases a compromise method is used and the bell is counterweighted about to the extent which will keep it shut when empty but not with the charge upon it. This requires less lift from the cylinder to open than the full counterweight method, and also requires less pull from the cylinder to close than the non-counterweight method. Of course the cylinder is made double acting in this case, which it need not necessarily be in the other cases, although it usually is. By this compromise method, and by equalizing the work on the up and down strokes of the cylinder, the latter can be made considerably smaller than when it is virtually or actually single acting.

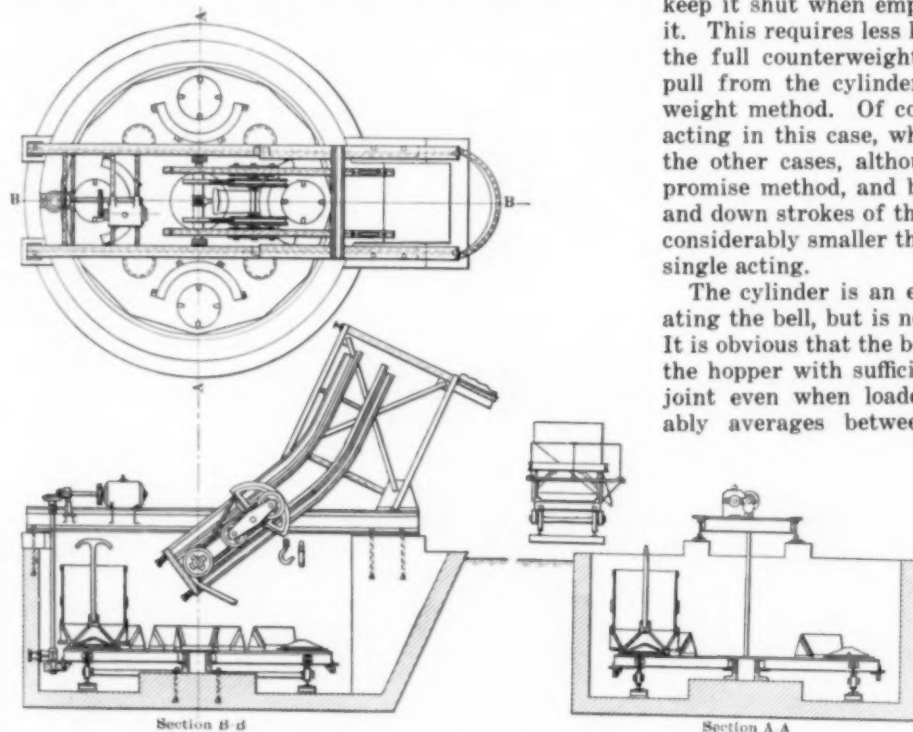
The cylinder is an extremely simple method of operating the bell, but is not a particularly satisfactory one. It is obvious that the bell must be held to its seat against the hopper with sufficient pressure to make a gas-tight joint even when loaded with the charge which probably averages between fifteen and thirty thousand pounds. The amount of work involved in opening and closing the bell is very small, and in order to be large enough to hold the bell shut or push it open by direct action the cylinder must be much too large for the real work it has to do, in order to form a satisfactory lock in holding the bell shut with the charge upon it.

On the other hand, any mechanism which exercises a

reasonable control over the bell during the dumping operation and likewise in closing so as to prevent excessive velocity is practically sufficient, except in the case of the full counterweight method.

It is very desirable to have a relatively slow movement of the bell at opening and closing so as to prevent slamming and violent inertia shocks on the whole mechanism. For this purpose the bell cylinders are piped as shown in Fig. 19. Inlet takes place through the pipe next the end of the cylinder, but discharge can only take place freely through the one further in from the end, since the outer one contains a check which prevents return flow, at any but a very slow rate, so that when the piston overruns the outer port it is cushioned by the steam trapped between that and the head of the cylinder, and its velocity thus checked at a rate slow enough to do no harm.

The cylinders generally require to be operated by steam as compressed air for such purposes is expensive and is likely to be frozen up in winter. When the bell cylinder is placed at the top of the furnace great care must be used to prevent the pipes leading to it from being frozen since there is no flow except when the bell is operated, and in severe weather during a relatively short suspension of filling a sufficient interval may occur between piston movements to permit this to occur.



FIGS. 27, 28 AND 29—BOTTOM OF FORD-PARKES SYSTEM

the rods. The bell-lever is connected to the rods by a short link as shown (but not very clearly) by the drawing.

Bell-Operating Apparatus

In the early days of the closed-top furnace the bell was probably always controlled by a hand-operated "crab," consisting of a crank and connecting rod driven by gearing. A large gear having a crank pin in its face was set immediately under the outer end of the bell beam and a connecting rod ran from a pin in the bell beam to the crankpin in the gear. When the pin was in its lower position the bell was shut, and the travel of the pin was such that when it was in the opposite position the bell was opened wide. A few of these crabs have remained in operation down to quite recent years, but they were superseded in general practice many years ago by a steam cylinder as shown in several of the preceding figures.

There are two methods of using the cylinder. One is to counterweight the bell so that it will stay shut even with the full charge upon it, and have the cylinder lift the counterweight to open it. This has the great advantage that if the steam connections are broken or any other mishap takes place, the bell remains closed and prevents the entrance of air into the top of the fur-

It will be seen that the crank and connecting rod has an absolutely smooth acceleration and retardation and that in the closed position it acts like an inverted toggle and holds the bell tight shut without expending any energy on it, so that it furnishes the ideal movement for this purpose. To make use of this ideal motion and to dispense with the necessity of steam or compressed air for operating bell cylinders an apparatus has been brought out in recent years which returns to the crank and connecting rod principle; but instead of being hand operated, as the earlier ones were, it is driven by an electrical motor controlled by automatic switches. The design brought out by the Otis Elevator Company is shown in Fig. 31. Fig. 32 on a smaller scale shows the arrangement of the crank in relation to the gear more plainly. The motor drives worm gears enclosed in the housing shown, and these in turn drive an internal pinion which meshes with the teeth of the annular gear. Automatic switches practically identical with those illustrated in connection with the furnace hoists control the movement of the apparatus. When the starting switch is closed the motor starts and runs until it has driven the main gear and the crank through a complete revolution, when it is automatically slowed down and stopped. This obviously opens the bell and closes it again. The only objection to this apparatus is its very considerable cost, and the necessity of having such an amount of machinery at the top of the furnace.

It may be said that while the cylinder has its disadvantages for operating bells, with certain modifications it could be made to do very much better than the direct acting cylinder, and in many ways almost equal to the expensive electrically operated apparatus without costing nearly so much.

The operation of gas seal bells is practically the same as that of large ones, although it requires very much smaller apparatus, since the loads to be carried are very much smaller and the small bell itself also weighs many hundred pounds less than the large one. In some cases now the upper bell is operated by an electrical bell hoist similar to but smaller than the one illustrated, for of course it is desirable to have both types of mechanism the same, to have either both steam or both electric.

These bells have generally been operated by cylinders working through levers the same as those used on the main bell, but several years ago Julian Kennedy of Pittsburg brought out a design in which the cylinder for the small bell was placed immediately over it in the center of the furnace in an inverted position, its piston rod becoming the rod of the small bell. This, of course, dispenses entirely with the lever for transmitting the motion, etc., but is open to the objection that steam must be on the cylinder practically all the time in order to keep the bell shut, or else a counterweight and lever must be used.

This design is followed with the rifle-barrel cylinder of the Baker top as already noted, but in that case the normal position of the small bell is open, so the cylinder is only under steam when the bell is being raised to close and rotate it.

Provisions for Access and Repairs—Means for Hoisting Main Bell

In the days when furnaces were hand filled and practically the only mechanism on the top was the single bell with its lever and bell cylinder, considerations of accessibility played no part, there being but little apparatus and that all in plain sight. When a bell had to be taken down from the top of the furnace or sent up it was hoisted out with some simple but powerful hoist; set on rails and skidded over to the platform of the hoist, commonly known as the cage, on which it was lowered

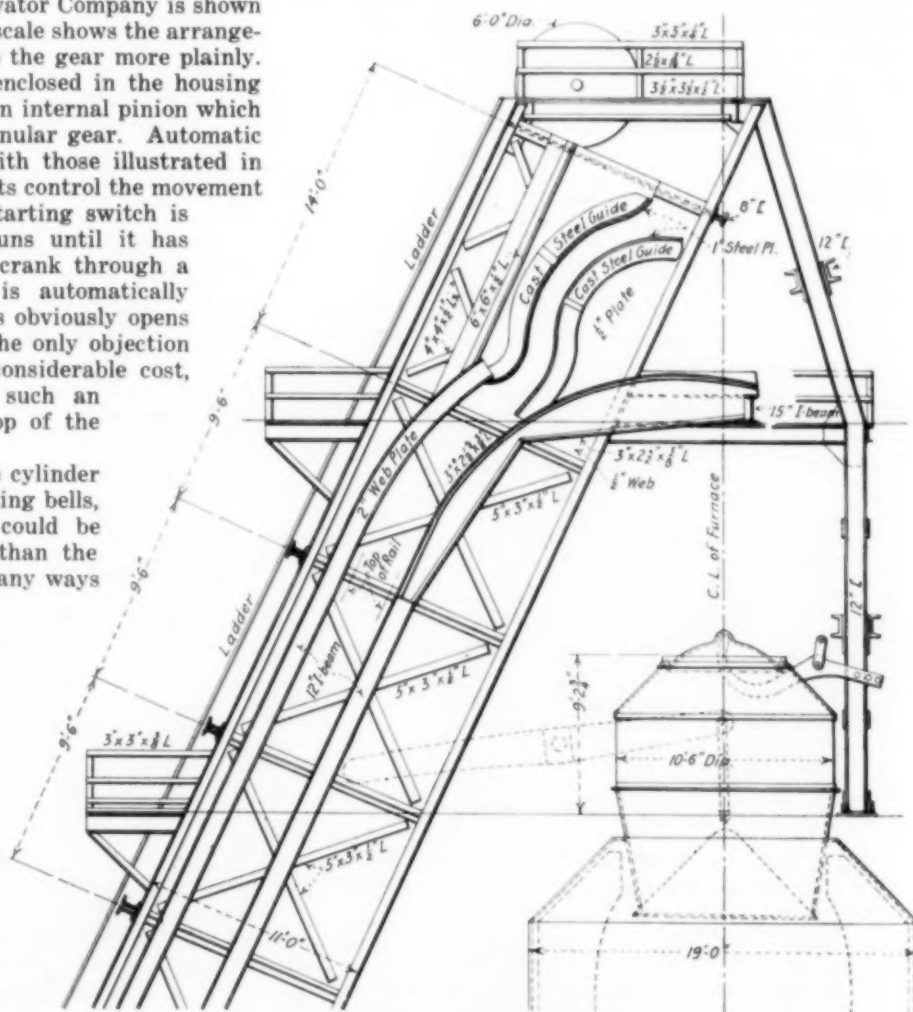


FIG. 30—TOP OF FORD-PARKES SYSTEM

to the bottom and a new one to replace it was brought up in the same way.

With the mechanical top all that is changed. There is in all cases a considerable quantity of machinery and in many designs a vast amount. This is erected when the furnace is built and is never expected to be removed until the furnace itself is torn down. The main bell is not only at the bottom of a hopper in many cases deeper than the height of a man, but is covered over by an airtight gas seal so that access to it is most difficult even for inspection, while before any repairs can be made a considerable portion of the top must be dismantled.

This is a point which has been too little considered in the design of furnace tops. Some engineer in a cool and pleasant drafting room designs some form of apparatus which pleases his fancy, and which may then be built easily enough because its construction is fundamentally no different from that of any other mechanical apparatus. But when the repairs become necessary

they are turned over to the operating man, and must be made under circumstances which may be conservatively described as follows:

The temperature of every part that needs to be handled is high enough to burn the hand, in many cases so hot that the radiation makes it disagreeable to approach. Every crack and cranny is filtered full of dust that at the best is packed tight, and if it has been rained on is cemented almost as hard as iron. The air is not only heated almost to the point of suffocation in many cases, but in practically every case is mixed with furnace gas containing 25 per cent carbon-monoxide, of which 1 per cent in the atmosphere is quickly fatal, and a small fraction of a per cent causes violent sickness. The nut of every bolt is either burned or rusted fast, or so jammed with dust that it will move but one "flat" at a time, and often will not start at all except with a sledge hammer and chisel. The room available on the top platform is generally just sufficient to permit bare access around the top of the furnace when everything is in place. The little space in which one might move with safety or speed is seized for the storage of parts as soon as the top is dismantled for access to the bell and hopper.

Under these circumstances it would seem as though some consideration might be given to accessibility and to designing some of the parts, notably the gas seal, so that they would go to place and function properly without the necessity of coming to an exact position, something which it is almost impossible to make them do after all this machinery has been subjected to the heat if not flame which are unavoidable at the top of a furnace, but this point appears to have been given very little consideration.

In quite a number of types the gas seal which rests on the lip of the main hopper supports the distributor; this means that in order to change bells the whole distributor must be taken off and the gas seal completely dismantled before the real work of removing the bell can be started.

It will perhaps illustrate the operating man's point of view to explain the former method of holding the lip ring down to its seat in the hopper. This was almost universally done with square bars resting against the lip ring at the bottom and passing through a socket near the top of the hopper, a key in a key-way through the bar just below the socket was driven by a sledge so as to force the bar down against the upper edge of the lip-ring, thus holding it to place. It is obvious that when the lip ring became loosened by the constant jar of the bell in closing, these keys could only be tightened by putting a man into the gas seal through a man-hole such, for instance, as that shown in Fig. 12, and having him drive up the keys.

It will be seen that he had to stand in a V-shaped space without a particle of footing, the temperature under the seal in many furnaces is seldom much less than two hundred degrees, even if means have been taken to cool it off, while there is almost certain to be a certain amount of gas leakage through the main bell and no chance of obtaining adequate ventilation through the small man-holes in the gas seal. I have known of at least one case where a man was killed by gas on going in under the gas seal to do some such work. The gas was not in sufficient quantity to be visible, and several men were rendered unconscious by it before the damage was realized, but by quick work on the part of the master mechanic all were taken out alive except the one.

In course of time the operating men determined that the holding bars for the lip ring must be tightened from outside the gas seal, and changed the construction to permit this, a practice which is now almost universally followed. The general principle of the method by which

it is done is shown on the left hand side of the hopper in Fig. 18.

Of course, neither the hoisting apparatus for the skip nor that for the bucket system of filling affords any possibility of handling the bells, and, therefore, some other provision must always be made for letting down old bells and bringing up new ones. This is very generally in the form of a runway extending well out over the side of the furnace, as shown in Fig. 12. In this case the runway is the same as that which carries the adjustable receiving hopper. When a bell is to be handled the hopper is removed and the trolley shown at the extreme left hand end of the runway is brought into action. This trolley runs far enough out so that the bell hanging from it in its outmost position clears the furnace entirely and may be brought up vertically; then when it is above the hand-rail the trolley is traversed over to

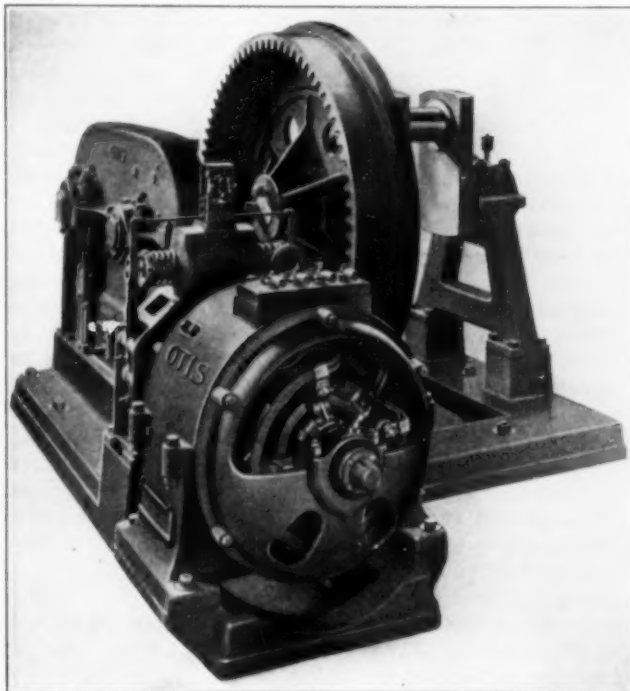


FIG. 31—DOUBLE SCREW INTERNAL GEARED ELECTRIC BELL HOIST, DIRECT CURRENT

the center of the furnace and the bell lowered into place. Sometimes a jib crane is used for this purpose, but in some cases within my experience these have been forced out of plumb by distortion of the furnace top and have been extremely hard to swing around, especially when under load. For this reason the runway with the traveler is probably much to be preferred. Ordinary hoisting arrangements cannot be used on the trolley on account of the great height of lift involved, and it is well to provide not only a trolley with its sheave, but to have some means of doing the hoisting quickly and safely.

Bells are certain to give out at intervals, probably their life does not average much over a year, and to have a good top design and good arrangements for hoisting and a top accessible without too much dismantling means the difference between a shut down of twelve and one of forty-eight hours.

The Stock Line Recorder

One of the most important points in connection with the filling of the blast furnace is to maintain the stock line at the proper height. With hand-filling this was frequently very difficult to do. The physical limitations of the apparatus, to say nothing of those of the men,

were such that if the furnace once "got down," that is if the stock line settled to a lower level than it should by the melting of the stock column below, it was very difficult to catch up as I have already explained. And if the stock line settles to the level which the stock should reach after it has been in the furnace for say two hours, then obviously the stock charged while that condition prevails is deprived of two hours of the time it should receive in treatment. This is frequently more than

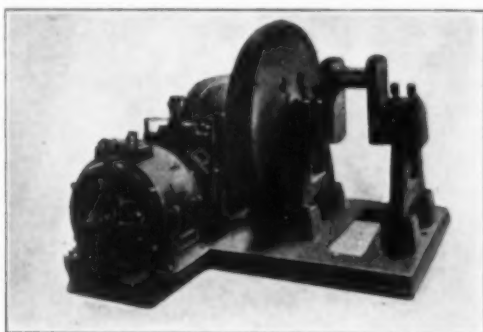


FIG. 32—BELL HOIST—CRANK END VIEW

enough to derange seriously the working of the furnace.

For this reason it is of great importance that the furnace shall not only receive in one twelve hours the complement of stock which it requires, but that this should be received at a uniform rate, and the stock line kept constantly within a very few feet of its proper position. When the furnace is filled with skips their capacity for handling materials is so vast that there is not often any physical obstacle to prevent the furnace from being kept full, but the very speed with which it may be charged may be a disadvantage since the men on the night shift may take a "spell" of an hour or two knowing that by hard work they can catch up by daylight, although the furnace may be "down" many feet when they begin to make up for the time lost, and its working deranged thereby.

Gaging rods working through the top of the furnace, generally through the hopper or a point just back of its upper edge, have been provided ever since the introduction of the closed top, and in recent years since the introduction of skip-filling, arrangements have been made whereby the test rod is suspended from a rope which winds on a drum at the bottom of the furnace, and by operating this drum the furnace can be gaged without the necessity of going on top.

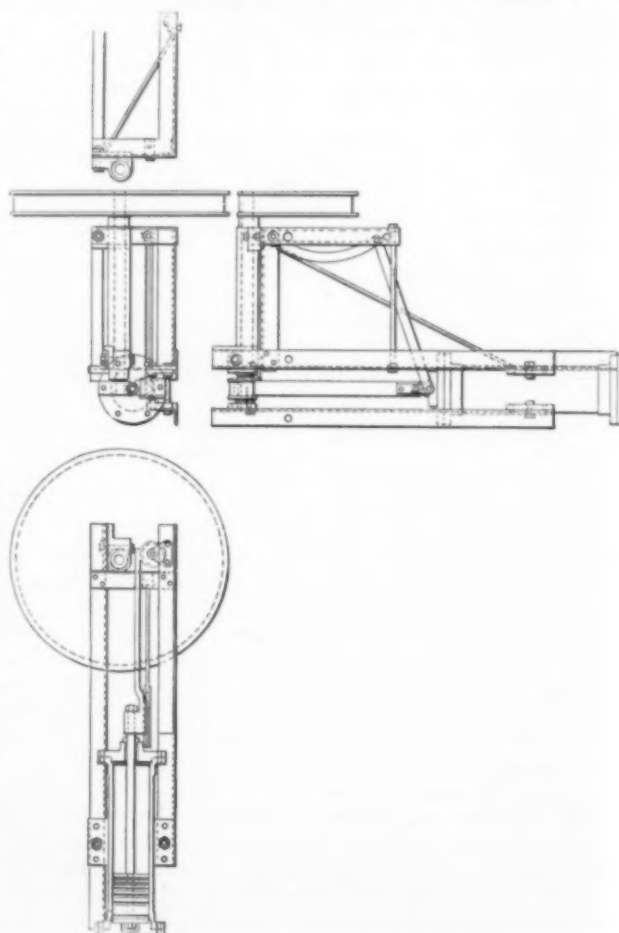
There is also another need to gage the stock line. This results from the fact that while the stock line ordinarily settles quite regularly, so many inches per minute, at times the furnace slips and the stock line will drop from two or three feet up to fifteen or twenty in moderate slips, and of course much greater depths in violent explosions and even though the furnace be working normally below it is much more desirable to have a record of the way the stockline is settling, so that any tendency to lag or work irregularly can be detected and cured without delay.

For the accomplishment of this purpose I designed several years ago an apparatus called a "Stock Line Recorder," of which the principle is very simple. (See *Transact. Amer. Inst. Min. Eng.*, Vol. XXXVI.) The test rod instead of being raised up out of action except when the furnace is to be gaged rests normally on the stock and settles with it. When the bell opens to admit the charge the test rod is drawn up out of the way, and when the bell closes it settles back on the stock in its new position, and follows it down until lifted for the next charge, and so on.

The mechanism by which this is accomplished is ex-

tremely simple, and the actuating portion of it is shown by Figs. 33, 34, 35. The test rod, which is made quite heavy, hangs in the furnace in the ordinary way. Light, flexible wire ropes are passed over a sheave on top of the furnace, and from thence to any convenient point, preferable near the skip operator's platform, where the actuating mechanism is placed.

The rope is wound on the narrow flanged drum, shown at the top in the plan view. This drum is keyed to a shaft, on the other end of which is keyed a small pinion meshing with a rack fastened to the piston rod of the cylinder shown below. The piston rod works through a metal gland with a fairly free fit so as to avoid friction. The piston is made quite heavy or else weight is attached to it in some way so that this weight acting through the pinion and drum tends to take up the slack from the test-rod rope, but on account of the much greater radius of action of the rope, and the considerable weight of the test rod, the weight of the piston alone cannot lift it. The top of the cylinder is connected to the main bell cylinder, generally without any valves or connections of any kind, so that when steam is turned on the main bell cylinder to open the bell it is simultaneously turned into the top of the recorder cylin-



FIGS. 33, 34 AND 35—OPERATING MECHANISM FOR STOCK-LINE RECORDER

der, and forcing the piston down raises the test rod to its highest or "safe" position.

When the steam is exhausted from the bell cylinder to close the bell it is simultaneously exhausted from the recorder cylinder, and the weight of the test rod with its greater leverage then lifts the piston in the cylinder until the test rod rests upon the stock, when it comes to rest and only moves thereafter as the test rod settles in following the stock down. The movement of the

mechanism is reduced by the lever shown in the back view (Fig. 34) and transmitted to the mechanical recorder, either of the dial or the strip type, and makes thereon a saw-toothed record as shown in Fig. 36. The amount of information obtainable as to the way the furnace is settling, whether steadily or by slips, is quite remarkable. One accustomed to the type of chart produced by a given furnace can tell by a glance at it whether the furnace is working normally or not, while the check on the fillers, on the human side, is an absolute one since it must work if the furnace is filled, and in a number of year's experience no method was ever found by which the machine could successfully be "beaten."

The subject of distribution is so vast, the number of variables and their reactions upon one another being practically infinite, and our knowledge of what the furnace really requires is so exceedingly limited, that the

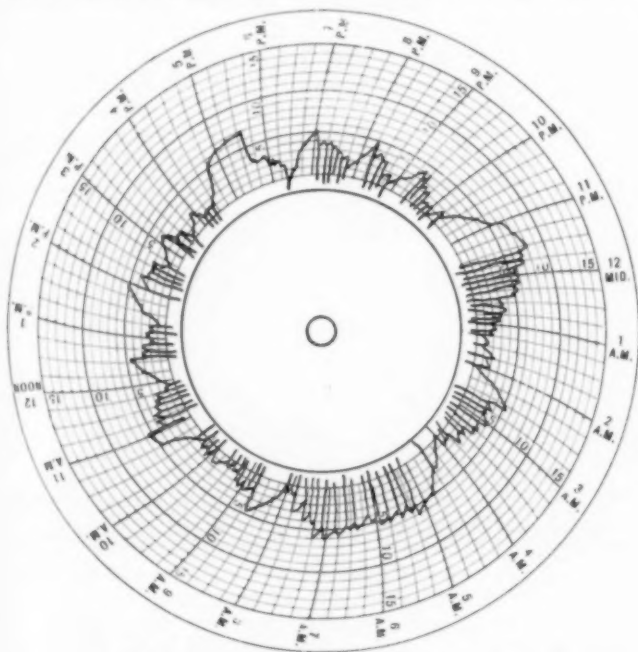


FIG. 36—CHART OF STOCK LINE RECORDER

little we know on the subject has only been developed by an utterly disproportionate amount of trial and experimentation, both with models and with furnaces, and by the slow process of elimination of the most unfit. It is probable that a book could be written upon the subject if one were willing to go back and compile the results of the experience of furnace men of the older generations.

But the question of whether we will or will not use mechanical filling for furnaces has been settled for us as have so many other questions, not upon the technical ground of whether its distribution is better than that of the hand-filled furnace, or the technical results better or worse than that of its predecessor, but by the stern law of necessity. The waning supply of men available for continuous heavy work, and the increasing wages which they command, combined with the absolute necessity of continuous operation irrespective of all other considerations, have forced us to adopt mechanical filling. There is no reason to believe that certain circumstances will ever alter so that large plants will be in a position to go back to hand-filling even if they should so desire.

It remains, therefore, only for us to use our best endeavors to find out the fundamental laws of distribution, and then to design an apparatus which will conform with those laws and survive under the conditions on the

top of the furnace. These are that any apparatus placed there shall receive a scant inspection surely not oftener than once a shift; that a shut down for its repair or for overhauling will be tolerated certainly not oftener than once in six months; that it must operate twenty-four hours a day, and seven days a week; that it must practically always be almost at the limit of working temperature for ordinary machinery; that it must be not infrequently exposed to a much higher temperature and often to flame itself, and that it must work in an atmosphere composed largely of the dust of one of the most abrasive materials in the world. That, further, it shall receive its material with irregularities depending upon a thousand circumstances, and shall smooth these out and deliver the material properly to its place on the main bell. That it shall pass pieces of scrap iron up to several hundred pounds in weight, two or three feet in length, and of almost inconceivable roughness, without injury to itself, and without delay, and that finally the total height through which the material must pass in the performance of these operations shall be a minimum so that the coke shall be broken up as little as possible.

If in the scant twenty years which have elapsed since the mechanical top became widely introduced we have not achieved perfection in all these results it is perhaps nothing to cause surprise. In contemplating the long distance we have come from the vast amount of expensive labor, the derangements of the furnace due to frequent inability to keep it full and for the horrible results of the early attempts at mechanical filling, I think we have every reason to feel, if not satisfied, at least that we have made great headway, in one of the most difficult tasks of designing ever submitted to the engineer and metallurgist.

Hydrometallurgical Treatment of Michigan Copper Tailings

BY R. D. LEISK

The Calumet & Hecla Mining Company is developing a combination regrinding and leaching treatment for the accumulation of tailings below its great mill on Torch Lake. If successful the method will probably be applied to all the old mill dumps in the copper country which can be profitably worked. The process may also solve the problem of treating mine rock in which the copper is so finely divided and flaky that losses in ordinary milling treatment are excessive.

The cycle of treatment can easily be followed by reference to the accompanying diagram, Fig. 1, in which, however, no attempt is made to show detailed arrangement of plant or machinery. It should be first explained that the Calumet & Hecla at one time milled rock containing about 90 lb. of copper per ton, and that the milling practice of that day allowed millions of tons of tailings containing 13 lb. or more copper per ton to flow into Torch Lake. With the increased extraction made possible by modern milling methods these tailings have gradually developed into an asset.

The old tailings are to be taken from the bed of Torch Lake by a main dredge and conveyed by a pipe line supported on pontoons to a storage pond on the shore of the lake near the new plant. Here a set of suction pumps will elevate the pulp to a set of dewatering and classifying tanks. The slime from these tanks will pass over a set of Wilfley tables and the tailings from the tables will go to the leaching vats. The concentrates from the tables will of course go direct to the smelter.

The sand from the classifying tanks will pass over dewatering screens onto a belt conveyor discharging into the storage bins of the regrinding plant which will contain 64 Hardinge mills. Pulp in the ratio of three

of water to one of solids will be fed to the mills at the rate of 35 tons per day for a 20-in. by 8-ft. mill. No classifier will be used on the discharge, as this would return coarse particles of copper for further grinding which is undesirable. The ground pulp will pass over Wilfley tables where free copper will be removed and the tailings discharged to the leaching plant.

The tailings which go into the leaching vats contain about one-half of the copper originally present in the sands. The chemistry of the leaching process depends upon a reaction well known in analytical chemistry, although its use for the recovery of copper on a commercial scale will be something new. The pulp contains too high a percentage of calcium carbonate for economical acid leaching. All copper which has gone through a milling treatment becomes covered with a slight film of

to complete the leaching treatment in a 91 to 96-hour cycle. In treating tailings containing 12 to 13 pounds of copper per ton it is expected to recover $5\frac{1}{2}$ to 6 pounds on the tables and from $4\frac{1}{2}$ to 5 pounds by leaching. The cost of leaching will be about 35 cents per ton and the recovery will be upwards of 70 per cent. The success of the process will depend upon how closely the working of the plant checks the results of the laboratory experiments, especially in the matter of losses of ammonia by volatilization. In the experimental work carried on by Mr. C. H. Benedict, the mill metallurgist, who has worked out the plans for the whole process, the working solution consisted of equal volumes of NH_4OH , specific gravity 0.93, and a saturated solution of $(\text{NH}_4)_2\text{CO}_3$. A more dilute solution will probably be used in the vats.

The plant is intended to run summer and winter. In winter the big dredge will be brought inshore and will dig in a small pond where the water can be warmed somewhat and kept in motion by the pumps. In summer the dredge, which has a greater capacity than the rest of the plant, will pump part of the sands into the excavation made the previous winter. The small pond in front of the second set of pumps is to give storage to tide over interruptions in the operation of the main dredge.

Work on the construction of the leaching plant has been halted temporarily, due to the general depression of the copper market, but the regrinding plant will be completed without delay. An interesting fact about the 40-hp motors which operate the Hardinge mills is that the electric power for them is developed by a low-pressure steam turbine driven by the exhaust steam from the stamps, which formerly was wasted.

Houghton, Mich.

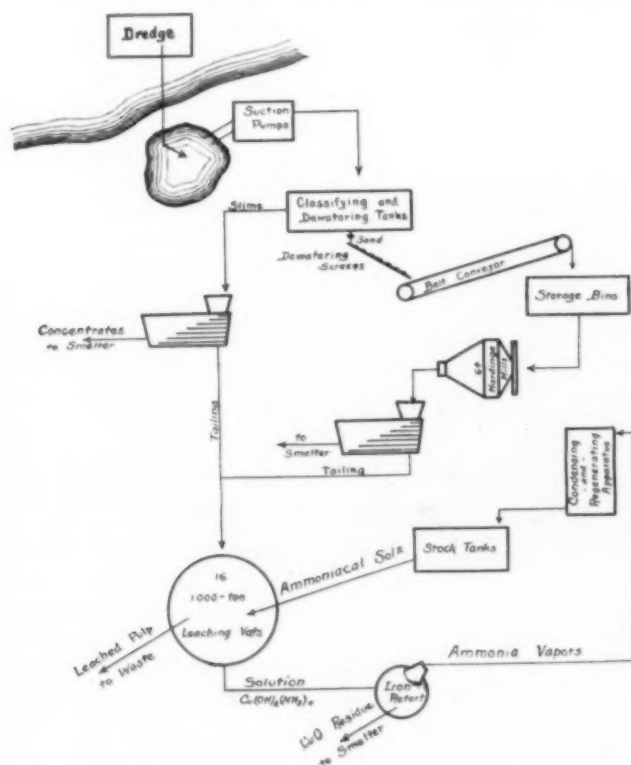
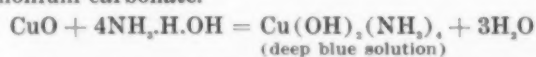


FIG. 1—DIAGRAM OF CALUMET AND HECLA COPPER LEACHING PROCESS

copper oxide which may be readily dissolved by ammonia in the presence of an ammonium salt such as ammonium carbonate.



If a supply of oxygen is present in the solution, the film of oxide is at once renewed and the process is continuous until all the copper is consumed. The copper which is now in solution in the form of a double cupro-ammonium salt may be precipitated as oxide by distillation in ammonia-tight iron retorts. The ammonia vapor is recovered and regenerated, and the precipitated copper, in the form of oxide, may be mixed with grades from the stamp mill and charged to a reverberatory furnace. The process was first worked out in Germany on natural oxides and roasted ores, but the Calumet & Hecla Company is the first to apply it to native copper. Early experimenters precipitated the copper as sulphide by the use of H_2S , CaS , and BaS , but this is wasteful of ammonia and leaves the copper in an undesirable form for Michigan copper smelting equipment.

Plans for the leaching plant call for sixteen 1000-ton vats 54 ft. in diameter and 12 ft. deep. It is planned

Safety-First, First-Aid and Welfare Work of the Colorado Fuel and Iron Company

The safety and welfare of the employees of the Colorado Fuel and Iron Co. are administered through the medical and sociological departments, with headquarters at Pueblo, Colo., where the company's Minnequa steel works and Minnequa hospital are located. The Minnequa hospital has long held an enviable reputation among institutions of its kind. In the wake of its development and in harmony with the growth of a world-wide sentiment, have come those other evidences of attention to the human element suggested by the phrases "first aid," "safety first," and "welfare work."

Committees on Safety

The administration of the safety department in the Minnequa works is under the direction of Mr. F. E. Parks, assistant superintendent, and in the hands of a central committee and department committees comprising officials and employees. Department committees are charged with the inspection of conditions within their respective departments, observing and reporting dangerous conditions and recommending safeguards for the protection of workmen. Dangerous practices and careless habits of employees that might lead to preventable accidents also come under their observation and are made the subjects of reports. The reports are considered by the central committee, the superintendent of the department concerned and the reporting committee and plans are then laid for improvement in the dangerous practices or conditions. As a final safeguard the committeemen regularly inspect the provisions for safety to see that they are intact and in good repair.

The safety department was organized on its present basis in July, 1911. In the three succeeding years the

company spent over \$20,000 in safety work. All stationary engines about the works have been equipped with automatic speed-limiting devices. Overhead traveling cranes are provided with railings and guards. Substantial platforms and railings have been erected along the trestles above receiving bins, and at overhead valves in the works. Permanent stairways have been substituted for ladders at many places and railings and platforms provided at elevated points from which a workman might fall during the discharge of his duties. Emery wheels are housed in adjustable steel guards designed at the works. Gears and motors are covered or surrounded by substantial iron-pipe railings, and guards are placed about moving belts to prevent accident in case of breaks. In some cases motors have been elevated so that the belts, properly guarded, run above the workmen's heads. In general, every precaution has been taken to prevent employees

"Loss of an eye, a hand or a foot, crippled, deafness, advanced tuberculosis in any form, epilepsy, fits or fainting spells of any character, active syphilis, running sores or any venereal disease, spinal affection heart disease, varicose veins, hernia, alcoholism, or any defect which would make it impossible for him to render regular and efficient service."

The diversity of races and nationalities represented among the employees adds to the problem of providing for their safety and welfare. Where men of only two or three nationalities are employed it is sometimes possible to post signs about the works, giving directions or cautions in several languages; but this is scarcely feasible where so many nationalities are represented. Table II gives a classification of 3689 employees of the Minnequa works, by races and departments as existing in August, 1914. The arrangement is in order of numerical predominance. Twenty-seven races are embraced. Americans predominate, comprising roughly one-third of the total; and for the most part they occupy the responsible positions. Aus-



FIG. 1—MINNEQUA HOSPITAL, WITH STEEL WORKS IN BACKGROUND

from becoming accidentally entangled in moving machinery.

The legend "Safety First" is before the workmen at appropriate places, as shown in several of the accompanying illustrations, being displayed with special prominence on a trestle in full view of all the men as they pass over a viaduct to enter the works. The numbered brass check carried by every employee also bears the same words stamped on its face.

Physical Examination Required

In order to secure a class of employees fit for work in the plant and to avoid the employment of men who, through previous physical disqualification might become a needless charge on the medical department, the company instituted in 1912 a system of examination for applicants. By this arrangement each applicant for employment is required to sign an application and record card and to pass a physical examination by a company surgeon. Table I shows the examination record. The examination is made at the Minnequa works dispensary without expense to the applicant. Boys under the age of 16 years and men over the age of 59 years or who are apparently under or over those respective ages, are not accepted for employment. Every employee is expected to be mentally and physically sound and fit for his work. An applicant is disqualified for employment if his examination reveals any of the following physical disabilities:

trians and Italians combined slightly exceed Americans in number and are employed mainly about the furnaces and in the mills.

TABLE I.—APPLICATION AND EXAMINATION RECORD

Full Name of Applicant	Address	Nationality Age Married
Signature of Applicant In Presence of Person Issuing Application		Dependents and Address:
Signature of Person Issuing Application		
Name of Nearest Blood Relative	Relationship	Address
Name of Nearest Obtainable Relative	Relationship	Address
What Sickness Have You Had?		
What Injuries Have You Had?		
For What Have You Been Operated?		
What Physical or Mental Defects Has the Applicant?		
Has Vaccination Been Recent Enough to Insure Protection?	Qualified Disqualified	Signature Examiner
Signature of Applicant in Presence of Examiner	Date	Place

Totals	Nationality of Race																		
	Americans	Austrians	Italians	Russians	Greeks	Negroes	German	Mexicans	Spaniards	Japanese	Irish	Slovakians	Hungarians	Polish	Swedish	Welsh	French	Servians	Croatian
247	61	83	8	11	8	47	1	1	1	1	1	1	1	1	1	1	1	1	1
438	109	137	40	13	44	20	1	1	1	1	1	1	1	1	1	1	1	1	1
424	178	106	106	11	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1
55	17	21	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
154	58	112	21	13	13	6	1	1	1	1	1	1	1	1	1	1	1	1	1
706	112	146	107	11	11	11	1	1	1	1	1	1	1	1	1	1	1	1	1
94	26	26	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
85	27	27	17	10	10	10	1	1	1	1	1	1	1	1	1	1	1	1	1
49	24	24	9	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
46	10	10	11	24	24	24	1	1	1	1	1	1	1	1	1	1	1	1	1
64	11	11	9	9	9	9	1	1	1	1	1	1	1	1	1	1	1	1	1
135	39	39	15	15	15	15	1	1	1	1	1	1	1	1	1	1	1	1	1
15	11	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
38	31	31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	11	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
64	38	38	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
64	52	52	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
79	32	32	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	13	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	13	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	15	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	16	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	4	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
150	11	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
90	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
32	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
31	12	12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
61	14	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
178	11	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	8	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	7	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	7	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
188	15	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
389	11	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table II.—Classification of Minnequa Works Employees by Races and Departments

Rescue Car for the Fuel Department

The fuel department, under the superintendence of Mr. E. H. Weitzel, maintains a rescue car for use at the company's coal mines. The car is equipped with first-aid cabinets, safety lamps, rescue helmets and various apparatus for use in case of coal-mine explosions. Training in first-aid and rescue work is given miners, who are granted certificates of proficiency on completion of a required course of instruc-



FIG. 2—STEEL WORKS DISPENSARY

tion. In order to aid employees in passing state examinations for responsible positions about the mines a correspondence school was organized by company officials and instruction was given by mail and through night schools in charge of representatives of the local division engineers. As a result of this work 265 men took examinations in 1913 and practically all were successful in securing state certificates as fire bosses and mine foremen.

Hospital and Dispensary Service

The proximity of the Minnequa hospital to the works, as shown in Fig. 1, and the location of the dis-

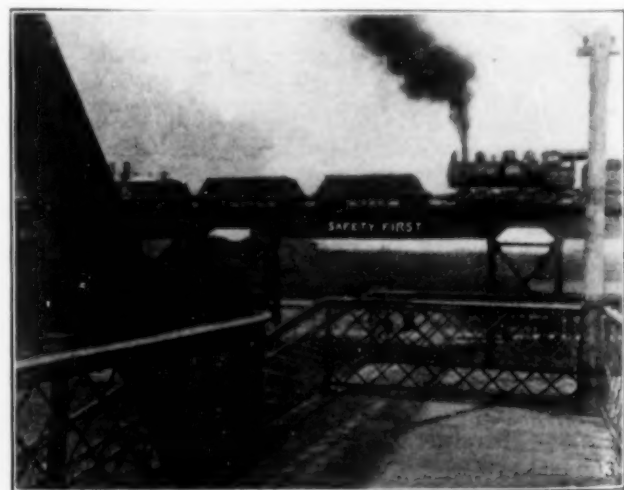


FIG. 3—SAFETY FIRST SIGNS ABOUT THE STEEL WORKS

pensary at the plant, Fig. 2, makes unnecessary the distribution of first-aid equipment throughout the various departments. The dispensary, under the direction of Dr. C. V. Marmaduke, affords medical treatment and handles minor surgical cases; gives vaccination to all employees without exception, and conducts an educational propaganda in prophylaxis. It is interesting to note that among the minor surgical cases, "foreign bodies in the eye" account for about 1000 each year, though the percentage of such accidents is

claimed to be no greater at the Minnequa works than in other outdoor occupations.

The good effect of the safety work in the plant and of the required physical examination of applicants for employment is reflected in the dispensary report for the year ended July 1, 1914. Major injuries have been greatly reduced and the efforts to conserve health have shown commendable results that cannot be attributed to chance. In the matter of physical examination the records show that the percentage of rejections has fallen from 25 per cent during the twelve months following the adoption of the system to 15 per cent at the present time. This decline is accounted for by the general knowledge among possible applicants that the physical requirement for acceptance is held at a certain standard.

The Minnequa hospital affords treatment for sick and injured employees from the coal mines as well as from the steel works. The expenses and full railroad fare to and from the hospital are paid by this department. Employees who are helpless through permanent injury received in the company's service are kept at the hospital indefinitely, some having been



FIG. 4—SAFETY FIRST SIGNS ABOUT THE STEEL WORKS

there as long as 20 years. When space permits, the hospital is open to private cases on usual terms. This practice helps defray running expenses, aids in the maintenance of a competent staff and affords evidence to employees that they receive the same treatment as that accorded to patients who pay for the service. Even with this income, however, added to that received from the monthly charge on all employees, the company finds it necessary to meet an annual deficit for hospital maintenance.

Hospital Innovations

Under the direction of Dr. R. W. Corwin, chief surgeon for the company, the hospital has evolved from a small frame building containing 25 beds, in 1880, to the present magnificent institution with 216 beds. It is characterized by many innovations instituted by Dr. Corwin, that are not found at many other similar institutions. There are no stairways. The outer approach to the administration level, and inner connections between floors are by inclines on a grade of one foot in six, contributing to the ease with which healthy as well as sick persons can pass or be taken from one floor to another. This construction is illustrated in Fig. 6. Floors are covered with cork carpet; doors are of the noiseless swinging type and cannot be "slammed."

Every possible provision is made to eliminate dirt,

odors and noise. Hospital signs bear the usual inscription "Safety First," and then admonish the reader to observe "Quiet Next." Special laboratories are provided for pathological and X-ray work. The operating room is specially interesting, having its floor, ceiling and three walls constructed of a continuous sheet of lead, while the fourth wall is formed of a large sheet of plate glass. The effect of the dull lead is to eliminate reflection of cross-lights, and it forms a surface



FIG. 5—SAFETY FIRST SIGNS ABOUT THE STEEL WORKS

that can be cleaned and sterilized by a jet of live steam.

For the education of employees in matters pertaining to health the hospital publishes regularly the *Sanitary and Sociological Bulletin*. This contains timely articles written in non-technical and popular form and is distributed free of charge. Illustrated lectures and entertainments are given periodically at the hospital chapel and residence.

Welfare Work

Special welfare work is conducted in the coal camps for the benefit of the miners and their families, under the direction of Rev. E. S. Gaddis, assisted by numerous

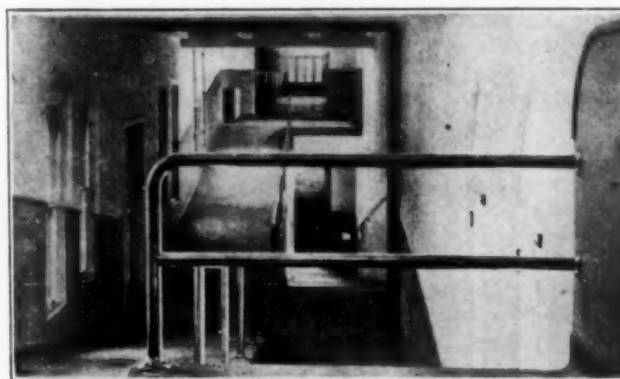


FIG. 6—VIEW OF INCLINE MINNEQUA HOSPITAL

local workers. Local company surgeons attend employees and their families, and maintain sanitary conditions in the camps. Education is under public control and regulation, as elsewhere in the state; but it receives attention from the sociological department, especially in the planning, lighting and ventilating of buildings and the activities of the pupils. First-aid exercises form a part of the instruction, even in the kindergarten. Reading rooms and social clubs are maintained for adults, and moving picture entertainments are given regularly.

The camps are also provided with churches, both Protestant and Catholic, in which services are held at regular intervals; and Bibles in several foreign languages as well as English are distributed free of charge.

During the recent labor troubles that occurred in the company's coal camps, saloons were closed by order of the State and remained closed during the greater part of 1914. From the opportunity thus afforded to observe the effects of enforced prohibition in the camps, the conclusion has been reached by company officials that the health, wealth and comfort of those communities were greatly enhanced. That this opinion was more widely shared is indicated by the fact that when the constitutional amendment for state-wide prohibition was before Colorado's voters last fall it was carried by large majorities in the strike districts where saloons had been arbitrarily closed for some time prior to election.

The Determination of Chromium and Vanadium in Steel

BY C. H. RICH AND G. C. WHITTAM

The oxidation of chromium by ammonium persulphate, as proposed by Walters,* has materially simplified the determination of that element.

Walters' method was proposed for the analysis of irons, usually of low chromium content. In adapting the method to the determination of chromium in steels, of 1 per cent or over, we have found that the oxidation of the chromium is incomplete in the volume of solution as prescribed by Walters. We have, therefore, modified the method to the extent of increasing the volume of solution at that point.

The combination of Walters' method for chromium and the J. Kent Smith method for vanadium, furnishes a very convenient method of procedure in the analysis of chrome-vanadium steels. Duplicate determinations of both chromium and vanadium may be carried through to completion in less than one hour and a single chromium determination may be completed in twenty minutes.

For those who prefer the internal indicator, the combination of the Walters and the Johnson methods, will be found convenient.

The critical points in the vanadium titration with the external indicator are the proper adjustment of conditions preparatory to the titration and the observance of a consistent end point, as subsequently to be described.

The Methods

CHROMIUM

One gram to 2 grams of the sample is transferred to a No. 4 lipless beaker and dissolved by heating with 40 cc to 60 cc dilute sulphuric acid (one part acid to five parts water). When in solution, 4 cc to 6 cc nitric acid (1.20 sp. gr.) is added and the solution is boiled until the iron is oxidized.

The solution is diluted to 170-180 cc and after the addition of 20 cc silver nitrate solution (1.33 grams per litre) is boiled during the addition of successive small portions of moist ammonium persulphate until the chromium is completely oxidized. The oxidation of the chromium is indicated in samples of low chromium content, by the precipitation of the manganese as dioxide, or, in samples of higher chromium, by the persistence of the pink tint of permanganic acid. The boiling is then continued a few minutes in order to decompose the excess of persulphate.

Two cubic centimeters, or slightly more if required,

of strong hydrochloric acid is added and boiling is continued until the chlorine is completely expelled.

The solution is then cooled and diluted to 400 cc, a measured volume of the ferrous sulphate solution is added and the excess is titrated with the standard potassium permanganate solution. The percentage content of chromium is ascertained by appropriate calculation.

The ferrous sulphate solution is in close agreement with the permanganate solution, which is approximately $n/10$, standardized against sodium oxalate.

The relative value of the solutions is found by titration of 2 grams of plain carbon steel under conditions identical to those in the actual analysis.

VANADIUM

The slight excess of permanganate representing the end point of the chromium titration, is discharged by the necessary additions of the ferrous sulphate solution; one to two drops of permanganate solution is added and the resultant pink tint is discharged by careful additions of the $n/20$ ferrous sulphate.

A measured volume of the ferrous sulphate solution is then added and the excess is titrated with the standard potassium bichromate. The end-point in the titration is the first appearance of the momentary flush which spreads over the drop of ferricyanide upon the addition of the test drop.

Very small drops of the indicator are used, spaced upon the clean and smooth paraffined surface of a porcelain plate.

The test drop is dropped on the edge, rather than directly on top of the drop of ferricyanide. If there is difficulty in distinguishing the flush, the test drop is placed on the plate and is blown into the indicator by gentle blast through a piece of glass tubing: the flush is thereby rendered distinct.

The relative value of the bichromate and ferrous sulphate solutions is found by adding to the solution of 2 grams of plain carbon steel the same relative volume of the ferrous sulphate solution as is to be used in the actual analysis and titrating with the bichromate solution under the same conditions of control as in the analysis.

A more convenient method of procedure in either the chromium or the vanadium titrations, is to ascertain the relation of the respective ferrous sulphate and the permanganate and bichromate solutions, in acidified water solutions, and in the analysis account for blanks as determined in solutions of plain carbon steel. Blanks so obtained appear to be consistent and need be determined or verified, only at intervals.

Some results obtained are:

SYNTHETIC STEEL

Chromium		Vanadium	
Added	Found	Added	Found
3.88	3.85	0.25	0.23
3.10	3.07	0.21	0.20
4.97	4.96	0.25	0.255
4.97	4.92	0.25	0.242
4.97	4.97	0.25	0.242
4.97	4.96	0.125	0.127
4.97	4.96	0.146	0.153
6.22	6.17	0.125	0.127

The following vanadium results were obtained in synthetic steels of chromium content ranging from 3 per cent to 6 per cent but on which the chromium results were low owing to too concentrated solution in the oxidation of the chromium.

VANADIUM

Taken	Found
0.25	0.23
0.21	0.20
0.50	0.49
0.25	0.248
0.25	0.242
0.125	0.127

*Metallurgical & Chemical Engineering, Vol. XII—No. 5.

Standard Sample No. 30—Bureau of Standards	
Chromium	Vanadium
1.39	0.216
1.38	0.204
1.39	0.21
1.38	0.21

The results reported by the co-operating chemists on this sample, varied from 1.33 to 1.38 chromium with a mean of 1.35. The vanadium results ranged from 0.185 to 0.224 with a mean of 0.21.

Additional chromium was added to this sample with results as follows:

Chromium		Vanadium
Total	Found	
4.13	4.14	0.21
4.13	4.15	0.21

Laboratory of the Alan Wood Iron & Steel Company, Conshohocken, Pa.

Removal of Carbon Bisulphide from Coal-Gas

In London *Engineering* of February 19 an interesting account is given of a recent lecture by Mr. E. V. EVANS before the Society of Chemical Industry on the way in which, after many years of varied experimenting, the South Metropolitan Gas Company has succeeded in getting rid of the obnoxious carbon bisulphide always present in coal-gas. "To Mr. Evans and to his chief, Dr. Charles Carpenter, the main credit is due for this triumph of engineering chemistry."

The amount of sulphur compounds, mainly carbon bisulphide (CS_2) remaining in coal-gas after the extraction of the sulphuretted hydrogen or hydrogen sulphide (H_2S) is only 0.02 per cent. That really is the chief trouble. At such high dilution only reactions of high velocity are likely to be effective.

Three methods appear available for the removal of the CS_2 . The first rests on the absorption of both H_2S and CS_2 by lime or other alkaline earths and alkalis with the formation of a thiocarbonate. Unfortunately the lime absorbs also the carbon dioxide, which is a superfluous, though not an obnoxious, constituent of the gas, and prohibitive quantities of lime would be needed for this purpose. If not removed, however, the CO_2 decomposes the thiocarbonate; any oxygen present has the same effect, and attempts to regenerate the decomposed mass *in situ* have so far failed. The "athion" process, now on trial at Heidelberg, is open to the same objection that the carbon dioxide has first to be removed; the absorbent used there is alkaline cellulose. Absorption by solids is always slow, moreover; but liquid ammonia has not answered either; thus this first method is not promising.

The second method relies on the absorption of the CS_2 by amino compounds (aniline, toluidine, etc.) in the presence of a catalyst with the formation of thiocarbonylides, which form the starting point of the manufacture of artificial indigo by Sandmeyer's reaction. The products are volatile, however, and the cost of washing the gas with weak acids or oils to bind the amino compounds would be high.

The third method, which has now proved successful, is based on the observations by Vernon Harcourt and others that most of the sulphur compounds in coal-gas are decomposed and converted into hydrogen sulphide, H_2S (which is subsequently absorbed by iron oxide), when the gas is heated to 500 deg. C. Mr. Evans took this line of research up in 1908. He found that CS_2 was not decomposed when carried by a current of nitrogen, but that the reaction did take place, according to $CS_2 + 2H_2 = 2H_2S + C$, and was irreversible, moreover, when hydrogen or coal-gas acted as carrier for small percentages of carbon bisulphide; the presence of water vapor did not disturb the reaction, which, it is noteworthy, depends upon the action of hydrogen, not of steam. The presence of certain metallic catalysts, of large porosity (finely divided so as to offer large sur-

face) accelerated this reaction; the carbon liberated by the reaction was deposited in the pores of the catalysts, but could be burned out again *in situ*.

Iron proved the most active catalyst available at low cost; the decomposition temperature was 450 deg. to 500 deg.; for the regeneration (by combustion or aeration) of the catalyst, the iron had to be heated to 450 deg. for several weeks; iron pipes answered as containers for the catalyst. Having ascertained the suitable volume and weight ratios, and found that 80 per cent of the CS_2 could be eliminated by the new process without deteriorating by the heating the quality of the coal gas, Mr. Evans had an iron retort made to deal with 50,000 cu. ft. (instead of 10 cu. ft.) per hour. The jump was too great. In spite of the interposition of a tubular heat-interchanger, the enormous volume of gas cooled the catalyst so much that hardly any decomposition took place, even when the retort was red-hot outside, and when the regeneration of the catalyst was tried a hole was burned in the retort.

Attempts were then made with porous clay impregnated with metallic solutions. In that condition iron

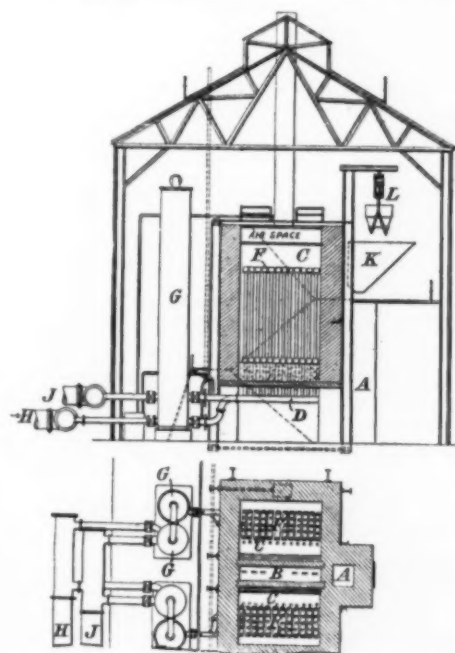


FIG. 1—PLANT FOR REMOVAL OF CARBON BISULPHIDE FROM COAL GAS

oxide was not active enough; nickel (reduced by hydrogen from the chloride) answered, but a higher temperature (600 deg.) seemed to be required for the reaction. That was undesirable, lest the coal-gas should be impoverished, and the deposition of carbon in the pores proved troublesome.

After a great deal of experimenting, in apparatus capable of dealing with 2000 cu. ft. of gas per hour, on the preheating of the gas, the amount, porosity, density and specific heat of the catalyst, the exposed surfaces of the catalysts and their containers and other features, a plant for 2,000,000 cu. ft. of gas per day was erected in 1911, and this was followed by a plant of five times that capacity (10,000,000 cu. ft. per day) in 1913. In these plants the gas is preheated by passing through 2-in. horizontal tubes before entering the four vertical reaction tubes, 6 in. in diameter, connected in parallel, the whole set being placed within the heating chamber. Such a unit dealt with 5000 cu. ft. of gas per hour, and in large plants a proportionate number of units were installed.

When Mr. Evans delivered his lecture the 1913 plant

had been in constant operation for almost two years, and, on an average, the percentage of sulphur compounds has been reduced to 2 per cent of the amount before treatment, that is, from 35 grains per 100 cu. ft. to 8 or 7 grains. In other respects the treatment makes little difference. The candle power and the thermal value are practically unchanged. There is a slight rise in methane (from 26.85 to 27.26). A little ammonia also results from the treatment. This is an advantageous feature, inasmuch as the ammonia keeps the iron oxide (wanted for absorbing the H_2S formed by the reaction) alkaline.

The catalytic material is a mixture of finely divided nickel (reduced from the chloride) and of a small quantity of nickel sulphide; the latter amount depends upon the ratio of H_2S to H in the original gas. Most of the sulphuretted hydrogen of the crude gas has to be removed before the treatment, otherwise carbon oxysulphide (COS) is formed by the interaction of the CS_2 and the CO in contact with the hot catalyst, and the presence of this undesirable COS becomes perceptible when the crude gas contains more than 100 grains of H_2S per 100 cu. ft. The above-mentioned increase in the methane percentage would be greater if the reaction were conducted under different conditions; it is partly the presence of sulphur which keeps it so low in the process under notice, because sulphur acts as a poison as regards methane production in the presence of nickel. It is interesting, as Dr. H. G. Colman emphasized during the discussion, that nickel is poisoned as a catalyst by sulphur at 250 deg., but is so no longer at 450 deg. The contact between nickel and carbon monoxide might be thought to lead to the formation of nickel carbonyl; the Mond nickel reduction process is based upon the fact that nickel and carbon monoxide form a volatile compound at about 100 deg. C., which is decomposed with deposition of metallic nickel above 200 deg. C. The presence of this poisonous nickel carbonyl in coal-gas, from which nickel might afterward be deposited, would be most objectionable. No trace of nickel has, however, ever been detected in the gas treated by the Evans process, even when the working temperature had been lowered to 250 deg. C.; yet, to make sure of its exclusion, contact between the gas and the nickel is not allowed to take place at a temperature below 300 deg.

The latest and largest of these installations is the plant put up at East Greenwich in the early part of 1914. The capacity of the plant is 15,000,000 cu. ft. of gas per day; it is divided into five units, each of 3,000,000 cu. ft. The 2-in. preheating pipes have, at Greenwich, been replaced by heat-interchangers erected outside the furnace setting. The general arrangements are illustrated in Fig. 1. Each unit consists of a central producer *A* surmounted by a combustion chamber *B*; on both sides of *B* are heating chambers, in which a temperature of from 420 deg. to 440 deg. C. is maintained about the reaction tubes *F* containing the catalyst. The gas entering through the pipes *H* is preheated to a small extent in *C*; the chief preheating takes place in the heat-interchangers *G*, in which the gas flows in the opposite direction to that requiring treatment; *D* is the collector tube and *J* the pipe carrying off the treated gas; *K* indicates the hopper and *L* the coke-handling plant. When the catalyst is to be revived, the temperature in the heating chamber is lowered and air is pumped through the reaction tubes at a definite rate, this process requires about a week, during the first four days of which all the oxygen of the air is taken up by the carbon deposited in the catalyst and burned to carbon dioxide. When oxygen appears in the effluent gas the temperature in *C* is raised to 430 deg. C and is kept at that height until the evolution of CO_2 has ceased. The aeration period is

then complete, and before starting the decomposition the air left in the pipe system is swept out with waste combustion gases; similarly, the gas is swept out by combustion gases when preparing for aeration. The catalyst remains active in its tubes for thirty or thirty-five days, then the efficiency falls off and is restored by the aeration process just described. No deterioration of the nickel has so far been noticed after two years' working.

The capital outlay for plant per million cubic feet of gas per days was estimated by Mr. Evans to be about £1,500 (\$7,500) and the working cost at 0.3d. (0.6 cent) per 1000 cu. ft. of gas, this latter figure including interest on capital, depreciation, repair and maintenance. This expenditure is not prohibitive. As has already been stated, some sulphur—7 or 8 grains per 100 cu. ft.—is still left in the gas. This sulphur is mainly present as thiophen, but there are other organic sulphur compounds not yet identified. Various methods have been tried to remove them, so far without real success. In Sweden the carbon bisulphide itself has been eliminated by washing the gas with alcohol, which absorbs the thiophen as well as the CS_2 . This process is to be tried in England. The advantage of the alcohol treatment, as well as of the Evans process, is that the gas can be treated as such without previous removal of the carbon dioxide.

Standard Boiler Specifications

One of the most notable achievements of any engineering society is that of the American Society of Mechanical Engineers in connection with standard boiler specifications. This society some four years ago appointed a committee of seven prominent engineers to "formulate standard specifications for boilers and other pressure vessels and for care of same in service," in order to put an end to the increasing number of boiler explosions in this country and the resultant fearful toll of death and destruction.

The members of this Boiler Code Committee upon their appointment immediately set to work to draw up according to their best judgment a set of rules which would specify boilers of such high type that boiler explosions would be reduced to a minimum.

Each member gave unstintingly of his time and money to make this formulation of rules a success and, after three years of the most effective research work, a preliminary draft of rules was drawn up and sent confidentially to professors of engineering in prominent technical schools of this country, superintendents of inspection, departments of insurance companies, chief inspectors in charge of United States, State and municipal boiler inspection departments, prominent engineers known to be interested in the construction and safe operation of steam boilers, prominent manufacturers of steam boilers and editors of engineering journals—some two thousand persons. Each one was invited to read over this report, criticise the same and make any suggestions if they so desired.

An Advisory Committee was appointed in December, 1914, and from that time until the middle of February, they worked unceasingly, until the report was finally completed.

This report was presented to the Council of the American Society of Mechanical Engineers, February 13, 1915, and the Council voted unanimously to accept the report, and further than that, they voted to make the Boiler Code Committee and its Advisory Committee permanent under the name of the Boiler Code Committee of the American Society of Mechanical Engineers.

Fixation of Atmospheric Nitrogen

The fixation of atmospheric nitrogen was the subject of two papers presented on the evening of March 12, 1915, in a joint meeting of the American Institute of Electrical Engineers and the New York Section of the American Electrochemical Society. President Paul M. Lincoln of the American Institute of Electrical Engineers presided.

General Review of Nitrogen Fixation Processes

The first paper was presented by Mr. Leland L. Summers, of L. L. Summers & Company, Chicago, Ill., and gave a very good résumé of the whole subject. The paper is printed in full in the March issue of the *Proceedings* of the American Institute of Electrical Engineers (p. 337 to 371).

The three fundamental products formed by nitrogen are, first, its union with oxygen to form nitrates XNO_3 and nitrites XNO_2 ; second, its union with carbon to form cyanogen C_2N_2 and producing cyanides XCN and cyanamides XCN_2 ; third, its union with hydrogen, forming ammonia, NH_3 . The present industrial situation with respect to these three groups of nitrogen products is reviewed. The available nitrogen in the various compounds determines the price, at least as far as their use in the fertilizing field is concerned, and for a number of years it has been assumed that the selling price of combined nitrogen would be from 12 to 13 cents a pound.

The author gives a review of the different fixation processes which have been proposed, and then discusses at some length the theoretical limitations of arc processes on the basis of the thermodynamical theory of the equilibrium between N_2 , O_2 and NO and the reaction velocity of the formation and dissociation of NO —if the reaction is a purely thermal one. "We may assume that up to the present the [arc] processes in commercial use are limited strictly by the thermodynamic equilibrium of the Van't Hoff equation. As the volume of gases when working with low concentrations of NO are considerable, the radiation and convection losses as well as the transfer of sensible and latent heat from the arc to the gases lower very materially the temperature of the arcs, and the yields therefore indicate an average working temperature of 2200 deg. Cent. to 2500 deg. Cent. or concentrations of 1.5 to 2 per cent NO when working with air. These theoretical limitations of the direct process of forming NO have, therefore, led to many efforts to dissociate the nitrogen molecule by other means."

The common elements exhibiting the most pronounced tendency to combine with nitrogen (in the absence of oxygen) are Ca, Mg, Al, B and the carbides of a large number of metals. The author gives the theoretical reasons why for such processes the actions and reactions must not only be subject to accurate temperature regulation but the partial pressures must be controlled and it is probable that definite zones of reaction must be maintained.

Mr. Summers then takes up the description of those processes which have been commercially applied. Of arc processes for nitric acid production there are three: Birkeland-Eyde, Schoenherr and Pauling (all of which have been described and illustrated formerly in this journal).

The latest Birkeland-Eyde furnaces are of 3000 kw capacity and give concentrations of about 2 per cent NO and a yield of 580 to 600 kg of nitric acid per kw-year, or 65 to 70 grams of nitric acid per kw-hour.

The largest Schoenherr furnaces are of 800 kw capacity and maintain an arc 23 ft. (7 meters) long. They give an NO concentration of 2.25 per cent and a

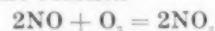
yield of 550 to 575 kg per kw-year, or 65 grams per kw-hour.

For the Pauling process the percentage of NO obtained is 1.25 to 1.5 per cent in the 400-kw furnace, while the yields are 525 to 540 kg per kw-year, or 60 grams per kw-hour.

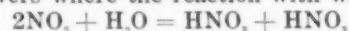
In all these processes where the arc is distorted the power factor is about 70 per cent, being about 5 per cent lower in the Schoenherr type.

All of the above concentration figures indicate that the maximum temperature of the arc is not utilized, but is very considerably reduced by the large amount of air admitted. If the temperature of the arc is raised by admitting less air there is a heavier decomposition of the products and all products are heated to a higher temperature with a corresponding loss, the net result being a lower yield per kw-hour. As the yield per kw-hour is of fundamental importance, adjustments are governed accordingly. The concentration of NO effects directly the apparatus for recovering the products, such as the absorbing towers, and the lower the concentration of NO the greater the losses from heating the inert gases. The furnace efficiency will largely be determined by this factor. A numerical example is figured out.

The author gives brief notes on Hausser's process utilizing coke oven gases by means of an explosion bomb, and points out that all of the above nitric acid processes utilize the reaction



which is an exothermic one for the formation of the peroxide, and if the temperatures are controlled, side reactions can be prevented and equilibrium can be maintained with only a small percentage of NO remaining. The gases after leaving the furnaces are usually carried through waste heat boilers where 50 to 60 per cent of the heat is utilized for steam production. They are then cooled in aluminium pipe coolers and allowed to enter a gas holder where time is given to form the peroxide. The products then enter counter-current absorption towers where the reaction with water forms



the nitrous acid HNO_2 is further oxidized and utilized to form HNO_3 in contact with the excess oxygen in the gases and with the absorbing water. The final recovery is usually made by circulating the gases through two towers of weak alkaline solution, such as sodium carbonate and this is converted into sodium nitrate and into sodium nitrite, and recovered by evaporation, the final products are a combined nitrate-nitrite of sodium. A normal circulation over three absorbing towers gives an acid of about 30 per cent concentration, but this can be increased to 45 or 50 per cent by recirculating over the first tower. Further concentrations are usually made by evaporation. All of these processes are simplified by increased concentrations of NO in the initial reaction. About 2 to 3 per cent of the original NO is discharged in the waste gases from the absorbing towers. It will be noted that one great advantage of these processes is that they require the handling of only air, gas and water up to the time the nitric acid is formed in the absorbing towers, so that the simplest handling devices suffice, and the labor is a minimum, also no chemicals are required until the final washing with the alkaline solution in the absorbing towers, and this may be a cheap solution such as lime water if conditions make it desirable.

The author then gives brief descriptions of the cyanamid process, the Serpek aluminium nitride process and the Haber synthetic ammonia process, and finally discusses the economics of nitrogen fixation.

Nitrogen is only one of the three important ingre-

dients of fertilizers, the other two being phosphorus and potassium.

"Prices of Nitrogen.—In general the price of combined nitrogen is fixed by the price of Chile nitrate. If this sells for 2 cents per pound and contains 15 per cent N, the price per pound of N is 13.2 cents and this in turn would make the price of ammonia sulphate having 21 per cent of nitrogen 2.7 cents per pound. These have been current prices. In considering the production of nitrogen products it would seem that while these prices control nitrogen for the fertilizer industry it would be desirable to produce if possible products which are manufactured from these crude products, and thus avoid competition with the natural products direct. Nitric acid of commerce is manufactured from soda nitrate by treatment with sulphuric acid, about 72 per cent of the sodium nitrate being nitric acid. As the by-products of this operation only partially pay the costs, the manufacturing costs leave the nitric acid with a value of 50 per cent over the value as nitrate. Hence chemical works could afford to produce nitric acid when they could not afford to add a manufacturing cost to produce a fertilizer from the nitric acid and then sell it in competition with the crude Chile nitrate.

"A large portion of the phosphate rock of this country is treated with sulphuric acid to form the so-called super phosphates. If nitric acid is used in place of sulphuric acid the super phosphate can be produced at the same time as a fertilizer of lime nitrate, or if preferred a high concentration of phosphoric acid can be produced from lower grade phosphate rock. Industries of this kind promise more favorable results commercially than does the direct production of fertilizer. If low grade products are manufactured at close prices a very large volume of business is a necessity and works of this character and magnitude are more apt to be a result of successful development rather than an initial venture in a field beset with uncertainties as to the profits and the chances of a development of other processes reducing these if they are problematical.

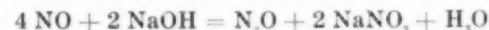
"Costs of Making Products.—Let us consider more in detail some of the costs. We may assume approximately that the labor and repairs in furnace room and absorbing tower will cost \$10 per ton of nitric acid and if nitric acid is selling for \$60 per ton, we have a margin for power cost, interest, general expense, etc., of \$50, and if we produce 500 kg of acid per kw-year it will require 2 kw-year per metric ton or \$25 per kw-year, and we must absorb all interest charges and general expense in this. If the yield can be made 550 kg per kw-year and we can sell for \$60 per short ton, we will require 1.8 kw-year, or \$28 per kw-year. We must assume that the product does not have to be packed for shipment and that there are no selling costs involved, and we must figure on an output so that our units may be large enough to bring the investment in plant down to \$80 per ton of acid so the annual charge may be \$8 or net \$20 per kw-year, and if \$5 are allowed for general expense the best we can do will be about \$15 per kw-year.

"We see it would be hopeless to attempt to put this acid into a product to compete with the fertilizer prices, for they are some 50 per cent lower in selling price, and it will involve a cost for some raw material to mix with the acid, the cost of manufacture and a packing and shipping charge. We must then abandon any idea of making fertilizer from nitric acid prepared by the direct oxidation of atmospheric nitrogen in the electric arc until such time as we can improve the very low efficiency due to the thermodynamic limitations of the reaction. We can only hope to utilize this process in

the manufacture of nitric acid coupled with some other product which will procure for it a higher price. There is for example a limited demand for the nitrite of sodium NaNO_2 used in the dye industry and this is manufactured by reducing nitric acid with molten lead thereby adding another manufacturing operation to the acid cost. This nitrite may be cheaply made by taking a mixture of NO and NO_2 such as we would have in parts of the system and passing it into water or sodium hydroxide, thus



or



and this process would produce a product selling for 4 to 5 cents per pound. We must remember, however, that the price of nitric acid is not a fixture and that a cheap combined nitrogen fertilizer will cut the price of sodium nitrate and hence the price of nitric acid. We are confronted then with the fact that all processes will be affected by the success of any one process that is a large enough success to affect the market conditions of combined nitrogen and upset the ruling prices in the fertilizer industry. It is useless to look only to cheap power as a solution of this problem as the real solution is in the improvement of processes.

"Let us roughly compare the power requirements of the processes as we have outlined them and we find

Direct oxidizing of atmospheric nitrogen 5 per cent. efficiency, yield at 550 kg. per kw-year, requires per kg. of N.....	65 kw-hr.
Cyanamide process 66 per cent efficiency in carbide, 1 per cent loss in heating to combine with N., requires per kg. of N.....	16.6 "
Also preparation of N.	
Aluminum nitride using coal to heat products to temperature of reaction requires per kg. of N.....	19 "
Catalytic method of combining N and H to form ammonia, requires per kg. of N.....	1.5 "
Also preparation N and H, refrigeration, and compression to 200 atmospheres.	

"The general tendency abroad in figuring the cost of water power is to give only the operating costs and from this one sees costs of producing power figured at from 50 cents to \$1 per kw-year and in using these figures erroneous ideas have been widely circulated. In this country it has been standard practice to consider the investment in the power plant, that is, the cost of the development and the property, as fixing very largely the cost of producing the power. It is quite common to have labor and supplies cost not more than \$1 per kw-year, but this would not be considered as representing the cost of the power. Where a chemical industry owns the hydroelectric power plant as well as the chemical works, the foreign practice is inclined to consider the investment as a whole and apportion the costs of operation to the various departments, while interest on the capital is charged to the profits. The costs of producing power are therefore uniformly much lower than we are accustomed to figure on. There are many plants in operation in the chemical industries abroad whose real costs of producing power are no lower than many of the more favored locations in this country.

"Off-Peak Loads.—One of the chief interests in the chemical utilization of electrical energy is centered in the possibilities of off-peak or off-season loads, as American plants generally have a certain proportion of power which can be disposed of to better advantage than selling the entire output as low priced power to chemical industries. This off-peak power is difficult to utilize in furnace work, where the cooling of the furnace and its charge is an important factor, both from the standpoint of cost and of output, and again adjustments may be so disturbed from an interrupted output as to be absolutely impracticable. One of the possible solutions for off-peak utilization appears to be in the adoption of some system where fuel is also utilized and the

radiation losses are not excessive under conditions of banked fire when the electric portion of the heat energy is not in use. Some of these combination processes may promise a solution of the off-peak load situation more attractive than the straight electric furnace, which is difficult to cool down entirely without unduly affecting the conditions. In all plants the volume of output is the determining factor in absorbing the general overhead charges, and any intermittance must diminish output with its accompanying disadvantages.

"If the furnace could be operated on the off-season load and its product stored, and the chemical works utilizing this product could operate on a normal schedule, this would form one solution; or another would be if by chance the off-season power were available at the time the greatest demands were to be met, such as preparing a fertilizer product at the season of fall rains for the early spring delivery. All of these plans, however suggest the necessity of operating at least a portion of the plant continuously in order to meet fixed charges and preserve an operating organization. If the chemical works requires a moderate amount of power for its processes in year around operation and only its surplus for manufacturing its crude material at the off season peak it promises the greatest possibilities."

Mr. Summers concluded that the future of nitrogen fixation is alluring and promises many developments along lines other than those considered, but already the market has felt the effects of these various processes and instead of nitrogen being figured at 13 cents per pound, it is confidently predicted it will very shortly find its level at a selling price of about 8 cents, making a cost of production of 5 to 6 cents per pound and thus reducing sodium nitrate to about 1.33 cents per pound, or approximately \$30 per long ton, and the lower grade mines will feel this and be forced to curtail.

The Cyanamid Process

The second paper of the evening was presented by Mr. Frank S. Washburn, president of the American Cyanamid Company, on the cyanamid process. As this paper is to be called up for discussion at the general meeting of the American Electrochemical Society in Atlantic City in April, we reserve a full report of the paper for our next issue and will give here a short abstract only.

In his paper Mr. Washburn pointed out that while the industries of the fixation of atmospheric nitrogen are only ten years old, they have reached a great commercial importance. The annual productive capacity of the existing plants employing the "arc" and "cyanamid" processes is between 90,000 and 100,000 net tons of fixed nitrogen, which, at the normal average value of the product at the factory door, represents \$25,000,000. This is divided in the ratio of two-thirds to "cyanamid" and one-third to the "arc" process. The American Cyanamid Company's factory at Niagara Falls, Canada, has alone a capacity in fixed nitrogen approximately half as great as the total world's installed capacity by the "arc" processes.

Mr. Washburn then took up the economic aspects of nitrogen fixation on the North American Continent. Nitrogen is used largely for three purposes: For crop fertilizer, for the production of nitric acid and its derivatives and for the production of ammonia. Nitric acid is relatively a small business, as great industries go. The fertilizer industry, on the other hand, is of immense importance.

Mr. Washburn pointed out the necessity of increasing crop yields without additional labor—that is, by the use of artificial fertilizers. European yields per acre cultivated are 50 to 100 per cent greater than American

yields. The use of fertilizers in Europe per acre cultivated is enormously greater than in America. The average increase in yield in Germany for the past twenty years has been approximately 60 per cent, in the United States 20 per cent. Abroad this increase is attributed to intensive farming, better selection of seed, the rotation of crops, and, to the extent of 50 per cent to 70 per cent of the increase, to the use of commercial fertilizers.

Mr. Washburn emphasized that if the American farmer is to use more fertilizer nothing is more important than to place at his disposal a high-grade chemical salt containing nitrogen and phosphorus, well balanced and in large percentages, and possessing in a high degree the many requisites of a good fertilizer, such as being non-hygrosopic, non-toxic, finely granular in form, non-leachable in the soil and readily convertible by nature's forces into the organism of the plant.

The author gave considerable data on comparative costs of the various atmospheric nitrogen fixation processes and their prospects in the United States. He thinks that the arc processes will be restricted to nitric acid field and it will not pay them to go into the nitrate business. On the other hand, the ammonia processes may go into the nitric acid field. The author's argument tended toward the conclusion that the cyanamid process seems destined to play the leading role in the fixation of atmospheric nitrogen in the United States. Unique in air nitrogen fertilizer processes is the direct and valuable application of the raw product cyanamid, as is proven by the fact that fully 80 per cent of the entire annual product of normally \$15,000,000 value is sold as the raw product. But there is also a long list of promising derivatives, ammonia, urea, cyanides and argon (used in the lamp industry).

Discussion

The discussion was opened by Dr. J. W. Richards, who reviewed the great progress made in recent years, but emphasized the "wonderful inefficiency" from the thermal and energy standpoint of all processes for the fixation of atmospheric nitrogen. The thermal efficiency of the nitric-acid arc process is only about 1.4 per cent, while the cyanamid process fixes about twice as much atmospheric nitrogen per kw-hour. There is a wide margin for improvement.

Mr. J. L. R. Hayden, in a communicated discussion, said that a series of experiments in Dr. Steinmetz's laboratory with arcs of different temperatures (produced by using different electrode materials, iron, titanium, carbon and copper) showed no direct relations of the NO concentrations to the arc temperature. He considers that the essential phenomenon in the arc is the dissociation of the oxygen and nitrogen molecules into N atoms and O atoms, which pass out of the arc and combine with each other according to the probability law.

Mr. D. B. Rushmore emphasized that our civilization is absolutely founded on the layer of from 4 to 6 in. of soil on the surface of this earth, and the conservation of this layer is an absolute necessity, and we have still very much to learn on fertilizing. He suggested the possibilities of development of water powers in agricultural districts and asked as to the effect of the electric field in arc processes.

Dr. C. A. Doremus referred to a treatise published in 1802 by Felix Pascalis, in which he referred to the possibility of manufacture of nitric acid from nitrogen of the air according to the expectations of Citizen Guyton. It has required a world conflagration to make us in this country appreciate our possibilities.

Mr. F. V. Henshaw asked as to the requirements of geographical location of nitrogen fixation plants.

Mr. Washburn replied that for pure cyanamide factories interior water power plants serving adjoining agricultural districts would do, but for the manufacture of ammonia-phosphate fertilizers cheap water transportation is as necessary as cheap water power. He said, however, that the beef-packing business was successful in spite of very large shipping bills, and a great nitrogen industry will be also able to face successfully similar handicaps. But this means manufacturing at one point on the largest scale.

Mr. Summers, in closing, said in reply to Mr. Rushmore's last question that at the high temperature of arc processes dissociation is so active that though there was an electrical effect it would be overcome and the final effect is purely thermal. Ozone, on the other hand, is produced at low temperature.

Chemical Reactions at Low Pressures

On the evening of Friday, March 5, in a meeting of the New York Section of the American Chemical Society, held in the Chemists' Club in New York City, the Nichols gold medal was presented to Dr. IRVING LANGMUIR, of the Research Laboratory of the General Elec-



IRVING LANGMUIR

tric Company, Schenectady, N. Y., for his research work on chemical reactions at low pressures.

The presentation of the medal to Dr. Langmuir was made by the chairman of the Section, Professor Allen Rogers, in a felicitous little speech. Dr. Langmuir, in expressing his thanks, modestly laid great stress on the help and co-operation he had had in his research from others. Dr. Langmuir then presented a long formal paper on "Chemical Reactions at Low Pressures," of which we herewith give a brief abstract.

In the course of the author's investigations into the causes of the blackening of tungsten lamps the effects produced by the introduction of low pressures of various gases were studied in considerable detail. It had been previously known that the vacuum in a lighted tungsten lamp normally improves during the life of the lamp, but it was thought that this removal of the residual gases was brought about by electrical discharges in much the same way as that commonly observed in Geissler and Roentgen ray tubes. These experiments have shown, however, that a highly heated tungsten filament will cause the disappearance or clean-up of nearly any gas introduced into the bulb at low pressure, and

that this action, in the great majority of cases, is purely chemical in nature.

The experimental methods that were employed in these investigations are relatively simple. A bulb containing one or more short filaments, usually the tungsten, was sealed to an apparatus consisting essentially of a mercury Gaede pump, a sensitive McLeod gage for reading the pressure, and an apparatus for introducing small quantities of various gases into the system and for analyzing the gas residues obtained in the course of the experiments.

By means of the pump the pressure in the system could be lowered to $2/100000$ of a mm of mercury. The McLeod gage gave a reading of 1 mm on the scale for a pressure of seven millionths of a millimeter of mercury. By means of the apparatus for analyzing gas, a quantitative analysis of a single cubic millimeter (at atmospheric pressure) of gas could be carried out, determining the following constituents: Hydrogen, oxygen, carbon dioxide, carbon monoxide, nitrogen and the inert gases.

In a typical experiment, after having thoroughly exhausted the whole apparatus, a small quantity, usually 5-20 cu. mm of gas, is introduced and the filament is electrically heated to a definite temperature, while readings of the pressure are taken at regular intervals (usually one minute). By plotting the pressure readings against the time, a curve is obtained which clearly shows how the rate of clean-up varies with the pressure.

In this way the author studied the clean-up phenomena with many different gases and several different kinds of filaments. Most of the work was done with tungsten filaments, but in order to get a broader outlook over the field of low pressure reactions, filaments of carbon, molybdenum, platinum, iron, palladium and other metals were also tried. The principal gases studied were oxygen, nitrogen, hydrogen, carbon monoxide and dioxide, chlorine, bromine, iodine, methane, cyanogen, hydrochloric acid, argon, phosphine and the vapors of many substances, such as mercury, phosphorous, phosphorus pentoxide, sulphur, etc.

With each of these gases, conditions could be found under which a heated tungsten filament will cause the clean-up of the gas. The curves obtained in the course of the experiments furnished very complete data for a study of the kinetics of the reactions involved.

Dr. Langmuir points out that the study of gas reactions affords the best means of studying the reaction mechanism, and that by the use of extremely low pressures the experimental conditions are enormously simplified. The reaction velocity is then much more intimately related to the behavior of the individual molecule than it is at higher pressures. The reaction velocity becomes a matter of statistics. The question is: Out of all the gas molecules which strike the surface of the heated filament, what fraction will enter into reaction with it?

Dr. Langmuir's researches related to reactions between gases and heated filaments, that is, heterogeneous reactions involving a solid and a gaseous phase. Comparatively little work has been done in the past on heterogeneous reactions.

It was at first thought that the law of mass action could be applied to heterogeneous reactions just as to homogeneous reactions. Experiments soon showed, however, that other factors than purely chemical ones usually determined the velocity of these reactions. Noyes and Whitney (*Zeit. Physik. Chem.*, vol. 23, p. 689, 1897) studied the rate of solution of solid substances in liquids and concluded that the velocity was dependent entirely on the rate at which the dissolved substances could diffuse out through the thin layer of liquid next

to the solid. Stirring the liquid had the effect of thinning this layer and so increased the rate.

Nernst extended this idea and suggested that the velocity of heterogeneous reactions in general was limited by the rate of diffusion of the reacting substances through a "diffusion layer," which he considered, under ordinary circumstances, to be of constant thickness. Thus he reasoned that the velocity of these reactions in practically all cases should be proportional to the concentration of the reacting substances. In other words, the reactions should follow the laws of monomolecular reactions. Nernst pointed out, however, that it was wrong to draw conclusions as to the mechanism of heterogeneous reactions from velocity measurements.

Dr. Colin G. Fink (Dissertation Leipzig 1907: see also Bodenstein and Fink, *Zeit. Phys. Chem.*, vol. 60, p. 1, 1907), as a result of his study of the kinetics of the sulfur trioxide contact process, developed a theory of the mechanism which marked a new step in our conceptions of the mechanism of heterogeneous reactions. Bodenstein and Fink (*Zeit. Phys. Chem.*, 60, 46, 1907) successfully applied this theory to a large number of other catalytic reactions.

This theory differs essentially from Nernst's in that the reaction velocity is assumed to be limited by the rate of diffusion of the reacting bodies through an adsorbed film of variable thickness. Thus, in the case of the reaction $2\text{SO}_2 + \text{O}_2 = 2\text{SO}_3$ in contact with platinum there is present on the platinum an adsorbed layer of SO_2 . The theory assumes that the thickness of this layer is at all times proportional to the square root of the concentration of SO_2 in the gas phase; in other words, that there is an adsorption equilibrium. The reaction is assumed to take place only at the boundary between the adsorption film and the platinum. The oxygen and sulfur dioxide must therefore diffuse through the film before being able to react.

This theory seems to have met with general favor and has been applied to the kinetics of many heterogeneous reactions. Dr. Langmuir proposes to modify Fink's theory slightly in that he assumes the reaction velocity to be limited not by the rate of diffusion through the adsorbed film, but rather by the rate at which the surface of the metal becomes exposed by the evaporation of single molecules from an adsorbed layer one molecule deep.

Dr. Langmuir gave in his paper a concise review of some of the fundamental principles of the kinetic theory of gases and followed this by pointing out the essential differences in his low-pressure experiments with filaments, and the conditions that would prevail if higher pressures were used.

At pressures as high as atmospheric pressure, convection currents set up by the filament produce very serious complications. At pressures of a tenth of a megabar* or less, convection currents become negligible for most purposes, but the problem is still complicated by the sharp temperature gradients that occur in the gas around the wire. At ordinary pressures, unless the velocity of the reaction is extremely small, the rate of reaction is determined largely, if not wholly, by the rate at which the reacting substances can diffuse to the surface and the products diffuse out. Under these circumstances, we should expect Nernst's theory to apply in general, but in this case we are really not measuring the velocity of a chemical reaction at all; we are merely measuring a diffusion coefficient in a gas.

On the other hand, at pressure as low as 10 bars diffusion may be considered as practically infinitely rapid. At this pressure the free path of the molecules of most gases is very close to 1 cm. This is so large, compared

to the diameter of the wire, that it is evident that the molecules leaving the wire can in no way interfere with those approaching it. Under these conditions the gases don't need to diffuse through each other in the ordinary way. At such low pressures as those we may, in fact, look upon the gas as consisting of a swarm of molecules entirely independent of one another.

The velocity of the molecules around the filament is then determined by the temperature of the bulb and is entirely independent of that of the filament. There is thus no temperature gradient in the gas around the filament. The average velocity of the molecules striking the filament is definitely known, and in case two or more gases are present, the relative number of each kind of molecules striking the filament is also known, no matter how rapid the reaction may be.

An interesting feature, possible only with reactions at very low pressures, is the fact that the temperature of the molecules striking the filament is different from that of the filament itself. At ordinary pressures, because of the heat conductivity of the gas, the molecules striking a solid body are, of course, always at the same temperature as the body itself. This opens up new possibilities in studying the kinetics of reactions. The effect of separate variation in the temperature of two reacting substances can thus be studied. If it is the impact of the gas molecules against the surface of the filament which determines the velocity of the reaction, then this velocity should depend much more on the temperature of the bulb than on that of the filament, since the impact depends on relative velocity, and the velocity of the heavy tungsten atoms, even at high temperatures, is much less than that of ordinary gas molecules at room temperature. On the other hand, if the reaction velocity is determined rather by some condition of the surface of the filament, then the effect of bulb temperature will usually be negligible.

Another result of the use of low pressures is that the molecules of the products of a reaction, when they leave the filament, do not return again until after having made many collisions with the bulb. If the substance formed is a non-volatile solid, or can be condensed by cooling the bulb in liquid air, it is thus possible to make certain that the reaction does not take place as the result of two collisions, but necessarily occurs in one. In this way also it should be possible to produce many compounds which are very unstable at the temperature of the filament.

At sufficiently low pressure (about 1 or 2 bars) the molecules leaving the filament travel directly to the bulb without striking any other molecules on the way. Naturally, they have no chance of giving up any energy on the way to the bulb, and therefore (if we can speak of the temperature of a single molecule) reach the bulb with the same temperature as that with which they left the filament. This must give the most sudden cooling which it is possible to give, and there is then the minimum chance for the decomposition of the product formed if it happens to be unstable at some temperature between that filament and bulb.

Another important advantage in working at low pressures is that the velocity of even the most rapid reactions in this way can be slowed down sufficiently so that they can be studied quantitatively. The heat liberated by the reaction on the filament is usually so small as to be noticeable, or at any rate is not so large but the isothermal conditions may be maintained.

After his exceedingly interesting general exposition of what may be learned from the study of gas reactions at extremely low pressures, Dr. Langmuir discussed in detail the reactions which occur when a gas is "cleaned-up" by a heated filament. We can give here only a very brief summary of these parts of Dr. Langmuir's paper.

*1 bar = 1 dyne per sq. cm. 1 megabar = 1,000,000 bars and almost exactly = 750 mm. of mercury.

There are four classes of cleaning-up reactions.

(1) *The filament is directly attacked by the gas.*—A typical example is the clean-up of oxygen by a tungsten filament (*Journal Am. Chem. Soc.*, vol. 35, p. 105, 1913). This reaction is interesting in its bearing on the theory of molecular films. Reactions between chlorine and tungsten and between carbon and oxygen were also discussed, but more briefly, under this heading.

(2) *The gas reacts with the vapor given off by the filament.*—The reactions discussed by Dr. Langmuir under this heading were the clean-up of nitrogen by a tungsten filament (*Journal Am. Chem. Soc.*, vol. 35, p. 931, 1913) and by a molybdenum filament, the clean-up of carbon monoxide by tungsten, and the clean-up of oxygen by platinum.

(3) *The filament acts catalytically on the gas, producing a chemical change in the gas without any permanent change in the filament.*—A typical example is the dissociation of hydrogen into atoms in contact with a tungsten wire at low pressure (*Transactions Am. Electrochem. Soc.*, vol. 20, p. 225, 1911; *Journal Am. Chem. Soc.*, vol. 34, pp. 860 and 1310, 1912; vol. 35, p. 927, 1913; vol. 36, p. 1708, 1914, and vol. 37, 1915). The dissociation of the hydrogen does not occur in the space around the wire, but takes place only among the hydrogen molecules which have been absorbed or dissolved by the metal. Other examples of catalytic reactions discussed by Dr. Langmuir are the dissociation of chlorine into atoms, the dissociation of oxygen into atoms, and the reaction between carbon monoxide and oxygen in contact with platinum.

(4) *The gas is chemically changed, or is made to react with the filament by means of electric discharges through the gas.*—If a positive potential of 100 volts or so is applied to an auxiliary electrode in a bulb containing a heated filament, electrons are given off from the heated filament and these, in passing through the gas, may produce ionization. The positive ions then are attracted to the hot filament and strike it with high velocity. Under these conditions reactions often occur which otherwise would not take place. For example, if the gas is nitrogen, these positive ions will combine with the tungsten filament to form the nitride WN_2 , even at temperatures where there is normally no appreciable volatilization of the tungsten.

In the reactions considered by Dr. Langmuir the velocity of the reaction is limited by the rate at which the reacting molecules come into contact with each other.

With reactions occurring on the surface of the wire, only a small fraction of the surface was in condition suitable for the reaction. The rate of reaction in these cases was limited by the rate at which the gas molecules could strike that part of the surface where the reaction could occur. In no case was there any evidence that the reaction was limited by any diffusion process in the ordinary sense.

In the case of reactions where the gas combined with vapor from the filament, the rate was again limited by the rate at which the molecules came in contact. All those that made contact reacted.

Only in two cases was it possible to measure a velocity which was not limited by such purely physical factors. These cases were the combination of nitrogen with molybdenum vapor and the attack of tungsten filament by carbon monoxide with low bulb temperatures. It is remarkable that in both these cases the temperature coefficient of the reaction velocity was strongly negative. In all the other reactions the large positive temperature coefficient was due to the fact that the rate of evaporation of the filaments or of absorbed materials on them increases so rapidly with temperature.

Dr. Langmuir did not mean to imply that all truly

chemical reactions must have negative temperature coefficients, but the results strongly suggest that such chemical reactions are very common, but that their effects are masked by other physical factors having large positive temperature coefficients.

The number of chemical reactions previously known which have negative temperature coefficients is extremely small. Bodenstein cites one case, while Strutt found that atomic nitrogen recombines to form molecules much more rapidly at low temperatures than at high, and reasoned that a high translational velocity of the molecule should in general hinder rather than hasten the reaction. Strutt considered that rotational velocity of the molecules, on the other hand, favors the reaction and that this factor in the majority of reactions greatly outweighs that of the translational velocity. Thus reactions between atoms should always have negative temperature coefficients, since atoms cannot have rotational energy. Dr. Langmuir's work lends further support to Strutt's views.

The viewpoint developed as a result of this work with low pressure reactions is undoubtedly applicable to reactions at high pressures and also to reactions between solids and liquids. Dr. Langmuir expressed the hope that further work will lead in a similar way to a better understanding of the mechanism of homogeneous reactions.

The Proposed British Dyestuff Industry

A German Opinion on Great Britain's Prospects

In view of the serious attempts which are being made at present in Great Britain to create a British dyestuff industry, it is of particular interest to read what a prominent representative of the German chemical industries has to say about these endeavors.

In the *Chemiker Zeitung* of Feb. 13, 1915, Dr. OTTO N. WITT, who is professor of applied chemistry at the Charlottenburg Institute of Technology and who was employed in former years as a chemist of some British aniline-dye works, publishes an article on "The New English Dyestuff Industry," which we reproduce slightly abstracted in translation:

"The desire to develop a strong and complete coal-tar industry, the most important branch of which must be the manufacture of dyestuffs, is not only comprehensible but logical and natural in every country which owns large coal fields and has an extensive iron industry. Such a country is bound to install by-product coke ovens and will, therefore, find it necessary to make profitable use of the abundant quantities of the tar.

"It is also easy to understand that during the present war, when the interchange of products between nations becomes difficult and frequently impossible, the lack of a coal-tar industry makes itself more felt than in days of peace, when a highly organized shipping trade meets every demand. Thus it has happened that not only Great Britain, but also the United States of America, have been thinking of the establishment of a coal-tar industry.

"In both countries these efforts would have been made at an earlier date were it not for the fact that for many years an entirely unjustified prejudice against cooking in by-product ovens had existed, which only recently has been overcome.

"If, therefore, the desire for a coal-tar industry in England and in the United States is something that was to be expected in the course of natural development, nevertheless, it is grotesque that in the case of England this development is an outgrowth of the national idea that Great Britain has been harmed by Germany's technical development, although the latter was but a natural

development of a healthy, well-governed people with the will to live. . . .

"In many publications I have pointed out that no country is able to transplant the technical creations of another country as a whole. Therefore I hardly think that England's present efforts to establish a dyestuff industry after the German model will be a success. I will try to give the reasons for this opinion.

"I have formerly shown that the color industry has never been developed in England to any great importance, although it was started there under the most favorable conditions. For many years England had a monopoly on all coal-tar products; besides, by the war of 1870-71, she had become free from all competition in the dyestuff industry, so that she had the best opportunity for getting such a strong foothold among the consumers in the whole world that it would have been difficult to compete against her. From the chemical point of view the dyestuffs, although not numerous, which at that time were made in English works were absolutely equal to the products of continental Europe, as I know from my own experience.

"If some of the processes of manufacture were somewhat cumbersome, according to our present views, this was also true in many instances on the Continent, while at the same time the prices, even with expensive processes of manufacture, left a sufficient profit. The nature of these processes frequently depended on local conditions. As an instance I mention the manufacture of the fine alcohol blues. In the Swiss works they were made by repeated extraction of the crude blue by alcohol which at that time was exempt from taxes in Switzerland. In England, where always a high tax was levied on alcohol, an ingenious process was used, by which the blue base was dissolved in aniline oil; an equivalent quantity of aniline salt was then added, whereby the chlorhydrates of the triphenylrosanilines were formed. Of these that of the fine blue is quite insoluble in aniline; it therefore crystallizes out of the solution in magnificent leaves, glittering like gold, while the ordinary blue was recovered from the mother-lye by driving the aniline over with steam. In this manner and without the use of alcohol, although with the use of a solvent expensive at that time, such a complete separation of the two blues was accomplished in one operation that even to-day I would prefer this process above any other, if, perhaps for scientific purposes, it was necessary to completely separate the mixture of dyes resulting from introducing the phenyl group into ordinary rosaniline. In the industry, to be sure, the demand for a good light blue has been filled in a simpler manner by the use of pararosaniline, but this was accomplished only several years later.

"If, therefore, ability can not be denied to the older English color industry why has it accomplished so little? To this the English of to-day have the easy answer that the German competition has been the cause. But the unbiased observer will contend that of two competitors the one who was first on the spot and worked under more favorable conditions has the advantage. This was undoubtedly England. What was her shortcoming?

"Not one but several causes have acted together to bring about the result. One of them has been discussed to distraction on both sides of the Channel. It is the co-operation of scientific research with the industry. The English chemists, who are not numerous, but some of whom are very prominent, have emphasized this point in order to advocate an increase of their scientific and research laboratories. They conclude by way of inference that England, if provided with as many scientific laboratories as Germany would produce as large a number of well-trained chemists for her industry as

Germany does. They overlook, however, that it does not suit the character of the young Englishman to be trained to be a scientific assistant in the same manner as the German student who, owing to the system of examinations and promotions, is obliged for a time to do independent research work before he can think of earning his daily bread. Many a student would perhaps not do the former if he were not compelled to. After, however, he has gone through this wholesome training the acquired scientific habit will mostly stay with him during his later professional life. That is, if we want to be quite frank, the true reason for interrelation between science and industry in Germany. If we had to rely only on those who have been born with a desire for research work, the number of scientific assistants in the German industry would not be as large as it actually is.

"It might be said that Germany has established also in her industry a general compulsory service (the English call it "militarism") which bears such brilliant results in her army. Not every soldier can be a strategic genius. In the same way the great majority of the thousands of capable and reliable chemical engineers, whom Germany has at her disposition, do not claim to perform original and inventive work. They are quite content with the rôle of intelligent and reliable factors in a great system created and more and more developed in the course of time by the genius of a few organizers, which, once created, is self-maintaining and produces its own leaders as in a well-organized military power. It would be a pity if in our educational courses and in our professional work we were lacking this strict organization. The situation would then be as it is in England, where every young man from his sixteenth or seventeenth year thinks of earning a living and if he does not his parents or relatives will make him understand that that is the proper thing for him to do. In Germany there are thousands of fathers who starve so that their sons might have a college education; these are unknown in England. There it is the privilege of the well-to-do "upper ten thousands" to send their sons to the universities, at the same time giving them such large allowances that the young men are in a position to spend more of their time on expensive sport than on scientific work. As a consequence, the scientific institutes of the universities and especially their chemical laboratories must be called poorly equipped from our point of view. What they have is all that is necessary to keep up the style of the English universities as it is fixed by traditions of centuries.

"Those laboratories in England which are not quite as narrowly framed as the national universities proper and which enjoy more freedom are few in number, but they are the real cultivating grounds of chemical science in England. They serve the requirements of those who have an inborn desire to devote themselves to research work and who have the means to do so. But as the means are often lacking, nearly all of these institutions have so-called "evening classes," in which for a modest remuneration such people can partake whose day-time is taken up by their trade, but who have nevertheless a desire for scientific studies. That these courses are in many instances very thorough must be mentioned with praise, but it is evident that they cannot give advanced instructions for experimental work, not to speak of independent research work.

"These conditions are the reason that the English nation, perhaps more frequently than the German, has produced able, occasionally even ingenious, autodidacts in chemistry (I only mention Gilchrist Thomas), but they are also responsible for the fact that the great army of all-around useful, scientifically well-trained as-

sistants, as Germany has, to the good fortune of her industry, is entirely missing in England.

"It is not impossible that in England these conditions may change as completely as has been the case with some other things. Such a change is, however, as little probable as is the overcoming of two other evils in the color industry.

"From a technical point of view, the English industry has suffered from a lack of organization and of working records. This evil is connected more closely than may appear at the first glance with the lack of scientifically trained assistants. The English factories must, in many cases, entrust with the management of their works people who belong not even to the "semi-educated class," although they are frequently very handy and intelligent. As a natural consequence the working records in some instances are limited to chalkmarks. The more manifold a manufacturing process, the more dangerous is the lack of control.

This may perhaps have been remedied in some works, since the Americans have raised the control system to a kind of science, mainly in machine shops, and have thereby directed the attention of larger classes to the importance of scientific management. Nevertheless I doubt whether the greater number of the works of the English chemical industry have an organization which can be compared to that in most German plants. For the German works organization has been created chiefly by the talent of a few scientifically trained chemists who managed to permeate even the dry array of figures with the live spirit of investigation.

"Finally it was the insufficient commercial organization that was the greatest detriment to the older English color industry. This shortcoming has been openly and frequently admitted by the English themselves for other branches of industry, and there have always been people in England who have recommended to their countrymen to take as a model the activity and circumspection of the German businessman. But they evidently have often preached to deaf ears.

"We [the Germans] are accustomed to look upon the English as very able businessmen. They certainly are as far as the spirit of enterprise, far-sightedness and large commercial speculations are concerned. But the English are less fit for the organization of a trade which, like the sale of dyestuffs and of fine chemical products generally, requires that continuously all small details are observed without losing sight of the great viewpoints. For this purpose the many Germans who heretofore used to earn their bread in England have been useful members of the English commercial world and their absence will be seriously felt when, after the war, they are released from the detention camps and leave England.

"In the foregoing I think I have enumerated the most important reasons why the older English color industry, though started under the most favorable auspices, failed to keep step with the younger Germany industry and, in spite of all the beautiful speeches, has been forced more and more to the background. According to the English view, these are mere details. The new industry is to be started with the aid of the Government which is to advance some millions, for the larger part of which, however, the consumers of the new dyestuffs are to be held responsible.

"How about these dyestuffs? That they will leave nothing to be desired is, according to the English view, warranted by the names of the members of various committees which have been formed for the organization of this affair. Very many of these members I know personally well. These gentlemen, mostly well advanced in years, none of whom has so far been prominently active

in the color industry, will hardly be able to build a large factory and to manage it. In addition there are in the committee several, probably younger men, whom I do not know and among whom there are probably those organizing talents who now, all at once, shall stamp out of the ground what England for more than fifty years has in vain cried for and aimed at—a great organic chemical industry, strong enough to compete against the German industry in England and in the world's markets, and at the same time able to pay interest on the capital advanced for its foundation.

"In the latter point, which must not be forgotten, there lies the greatest difficulty of the whole enterprise. All the others may be overcome with the aid of an exceptionally favorable chain of circumstances. Whether the government or the textile industry of England advances the required large capital neither one nor the other can waive an adequate interest and amortization. This means that 12 to 15 per cent of the capital invested must be earned before any profit can be made. If we consider that every new enterprise has its infancy losses, that not only the new factories but in many instances also the conditions for their existence have to be created, no favorable prognosis can be made for a profitable development.

"The German and Swiss color works have accumulated in the course of many decades not only large reserves by most cautious and rational financing, but they have also written off the book value of their plants to a minimum. This ensures a continuous source of profit which is lacking for every new enterprise of the same kind. For this reason the founding of new color works, formerly so popular, has been discontinued in continental Europe entirely. Every financier to whom such a scheme would be proposed would immediately realize that the new enterprise would not be able to compete against the old large works. But England wants to make the experiment, after having heretofore always complained that her existing color works cannot exist against the German competition. If these factories had been managed chemically, technically and commercially in the right manner and if they had accumulated reasonable reserves they would have worked under nearly the same conditions as the German ones. Like these, they could have expanded long ago to very large enterprises which could have met the German competition under equal conditions. As they have not accomplished this, a new large enterprise is now to be founded, which under worse conditions is expected to achieve the success that was denied to the old works.

"Success of this undertaking could leave Germany, of course, entirely disinterested if it would not bring about certain very remarkable consequences. Not so much for the German color industry, which may be confidently relied upon to meet the new competition, but in the first place for the German textile industry. It cannot be denied that in a large number of products, and especially in those which by their higher value left a greater margin for clear profit to be realized, as fine worsteds and other woolen cloths, fine-filed cottons and linens, the German industry has not been equal to the English, as is evident from the import statistics. Just this English industry has heretofore largely used German dyestuffs, and just this industry is supposed to finance the new English color industry, or, in other words, to bear the unavoidable damage which it is bound to do. That means, of course, a weakening of this heretofore strongly founded English textile industry and consequently a strengthening of the German one. The latter must and will under all circumstances, after the war, strive to produce for the home market many articles which heretofore were bought from England, and the

total value of which probably balances the value of the chemicals exported from Germany to England. It can do so the more readily as long as England harms and cripples the exporting part of her own industry by new enterprises which are not created in a rational, commercial spirit, but which are the offspring of the passions of envy and of jealousy. For the German color industry the result will be that it will be able to dispose of a large part of what it has heretofore exported to England in the home market due to the expansion of the German textile industry.

"The whole affair reminds one very vividly of the famous 'Made in Germany.' The demand for this inscription on all German goods was a measure dictated by jealousy and based upon the supposed inferiority of the German products, which inferiority was so long talked of in England that it finally was believed. To-day it is generally known that the strict observation of this measure has furnished uncounted millions to the German trade. I can see no reason for any apprehensions on the part of Germany about the creation of the new English color industry."

Recent Chemical and Metallurgical Patents

IRON AND STEEL

Interlocking Brick for Hot-Blast Stoves.—In Fig. 1 is shown a form of interlocking brick for hot-blast stoves, patented by EDWIN E. SLICK, of Westmont Borough, Pa. The idea is to provide a brick which cannot become broken, shifted or thrown out of alignment due to the extreme changes of temperature which occur in such stoves, and the sudden blasts or explosions which sometimes occur. The drawing at the left of Fig. 1 shows a top plan view of a portion of brick work as constructed of the interlocking bricks, which are shown in plan and elevation at the upper and lower right respectively. (1,130,031, March 2, 1915.)

Alloy for Dynamo-Electric Purposes.—A patent of WALTER RÜBEL, of Westend, near Berlin, Germany relates to a process of manufacturing an alloy of iron technically free from silicon, phosphorus and manganese, and of a corresponding admixture of copper. The process consists in deoxidizing purified and superoxidized iron by means of a small quantity of alkali-earth metal added in the form of an alloy with copper. For example, calcium, equal to 4 per cent of the copper to be used, may be added in the form of an alloy with copper. The result will be an iron almost free from Si, Mn, P and C. (1,130,678, March 2, 1915.)

Plating or Galvanizing Machine.—Apparatus for plating or galvanizing structural bars, pipe and other objects of considerable length, is patented by CONSTANTINE G. MILLER, of Chicago, Ill., the patent being assigned to the Meaker Company. Previous attempts to galvanize angles and channels have been unsatisfactory for the reason that the gassing of the electrolyte permits an accumulation of hydrogen bubbles beneath the cavities of the bar, and thus prevent uniform plating. The present apparatus consists of a tank or trough through which the pieces to be galvanized are passed. The treatment is designed to be continuous and to yield uniform plating. The pieces to be treated are delivered into the machine on cathode bars, above and below which are supported suitable anodes. Mechanical

means are provided for transporting the pieces through the trough, and also for periodically turning them over so that accumulations of hydrogen are prevented. The agitation of the electrolyte, as well as the shock of the blow in turning the piece, serves to displace gaseous bubbles, keeping the plating surface clean. (1,128,481, Feb. 16, 1915.)

Gold and Silver

Vacuum Slime-Filter.—Apparatus adapted to filter ore-slime in the cyanide process, shown in plan and sectional elevation in Figs. 2 and 3, respectively, is patented by CHARLES G. OSGOOD, of Tonopah, Nevada. The patent is assigned to the Montana-Tonopah Mines Co. In general plan and method of operation the apparatus

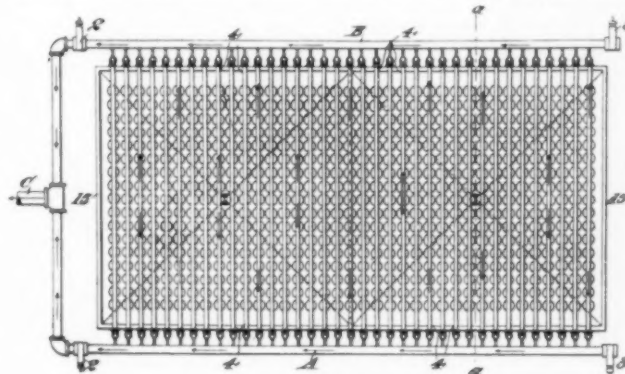


FIG. 2—VACUUM SLIME FILTER

resembles the stationary-leaf type of filter, with a large number of filter spikes substituted for leaves. Referring to the figures, the spikes 5 are supported from cross headers 4, which are all connected with manifold pipes A and B. The manifold pipes join at C and are in connection with a suitable pump, not shown. The entire filtering apparatus is contained in a tank 15. The spikes are formed with a tapered core of rectangular cross-section and having longitudinal corrugations on the sides, and a filter fabric enclosing the core. The inventor claims superiority over the leaf-type of filter in capacity per unit of space, economy and convenience of operation, and adaptability to various applications.

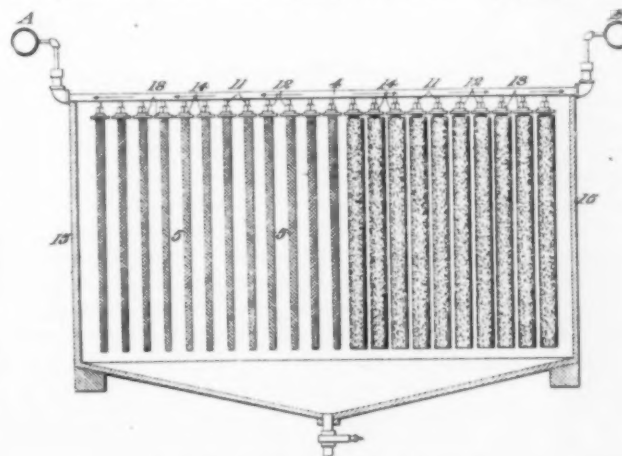


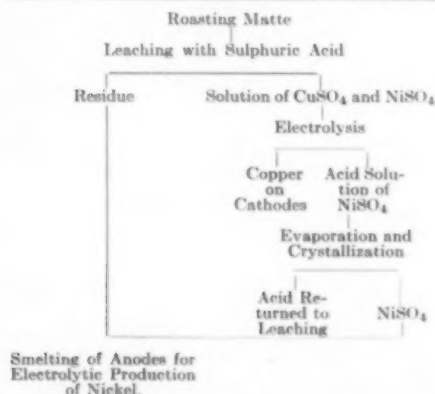
FIG. 3—VACUUM SLIME FILTER

It is further claimed the invention obviates certain difficulties encountered in leaf filters, such as unequal building of the cake, breaking and fracturing of the same, and cleaning of the filter leaf. (1,128,495, Feb. 16, 1915.)

Copper, Nickel and Zinc

Refining Copper-Nickel Matte.—In several patents recently granted to N. V. HYBINETTE, of Christiania,

Norway, the inventor discloses improvements on his method of refining copper-nickel matte which was noted in this journal, January, 1906. According to that process the matte was roasted, leached to remove excess of copper, smelted and cast into anodes and also into slabs for cementation of copper from the electrolyte containing copper and nickel in the form of sulphates, thereby regenerating the electrolyte in nickel, the copper replacing the nickel in the slabs. The process of producing the copper-nickel anodes is shown below.



The anodes thus produced are electrolyzed in an acid nickel sulphate solution, whereupon copper is cemented out from the solution on metallic slabs. A special form of cell is provided for this part of the operation. The inventor previously prescribed copper-nickel free from sulphur, carbon and silicon as the material for the metal slabs on which to cement the copper. He has now discovered that cementation is possible on slabs of copper-nickel containing 4 to 8 per cent sulphur, cast from a blast furnace, provided that the slabs have been used previously as anodes in a nickel-plating tank, thereby preparing their surfaces in such a way that cementation will take place. (1,128,313-4-5-6, Feb. 16, 1915.)

Removal of Cadmium from Zinc Ores.—According to a patent granted to GILBERT RIGG, of Palmerton, N. J., and assigned by him to the New Jersey Zinc Co., cadmium can be removed from zinc ores by leaching the ore with water containing sulphuric acid in sufficient amount to convert the cadmium oxide to sulphate. Even when the sulphuric acid radical is already combined with zinc as zinc sulphate, as in roasted ore, the leaching of such ore with water will result in the conversion of cadmium to the sulphate and its dissolution in water. In practice, zinc sulphide ore would be roasted and leached with water at or near the boiling point. The small amount of zinc sulphate left in the roasted ore would suffice to convert the cadmium into sulphate which would then be dissolved in the leaching water. Preferably the roasted ore would be introduced into the leaching solution rather than the reverse. (1,129,904, March 2, 1915.)

Tungsten

A process for producing tungsten powder is patented by ROBERT RAFN, of Porsgrund, Norway, and assigned to the General Electric Co. The production of amorphous tungsten powder by reduction of tungsten trioxide is usually difficult of accomplishment, as a crystalline product most often results. The inventor has shown, however, that by making the reduction in two stages, first with ammonia gas at red heat, producing the so-called blue tungsten oxide, and then with hydrogen at cherry-red heat, the resulting product is a tungsten powder of remarkable fineness. (1,130,197, March 2, 1915.)

Metallurgical Apparatus

Mixing-Drum for Ore-Flotation.—In Fig. 4 is shown a cross-sectional view of a drum patented by J. M. CALLOW, of Salt Lake City, Utah, for mixing and aerating ore pulps for treatment by the flotation process. The apparatus is designed to accomplish its purpose by less violent means than is usually used in the propeller type of mixer. Hitherto it has been customary to agitate and aerate the mixture and form the frothy float in one vessel; but in the present invention it is designed to mix and aerate the pulp in one vessel, namely, the drum under consideration, without forming a froth, and then deliver the mixture to another vessel or cell in which the froth is formed and recovered with the accompanying mineral.

The mixing-drum consists of a shell A, within which is a lining 16 of porous material adapted to permit the passage of air but not pulp and water. This lining is

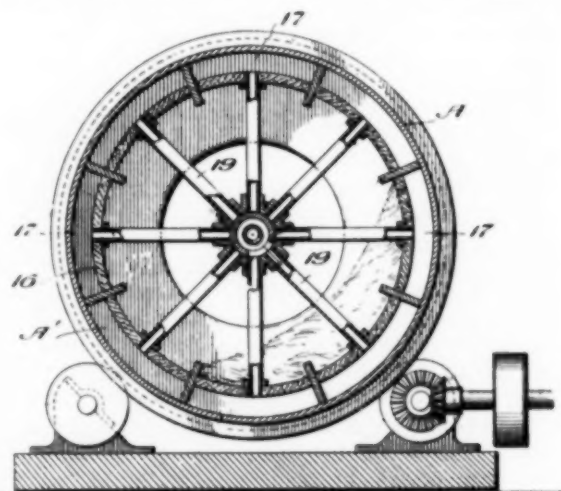


FIG. 4—MIXING-DRUM FOR ORE FLOTATION

spaced apart from the outer casing, forming chambers 17 between the two. The chambers are supplied with a series of pipes 19, for admitting air under pressure; and by means of a suitable valve the air is admitted into successive chambers during the rotation of the drum. Agitation and aeration are thus accomplished as the pulp flows through the drum from feed to discharge end. (1,124,854, Jan. 12, 1915.)

Metallurgical Furnaces

Electric Casting Furnace.—An electric furnace specially adapted to the cast of metals or alloys of high melting point is patented by A. L. J. QUENEAU, of Philadelphia, Pa. (now in the war with the French army). The furnace consists of a shell of suitable form, containing a crucible in which the melting is done. A combined casting nozzle and electrode extends into the crucible. Both the crucible and nozzle are kept at a high temperature to maintain the metal in a fluid condition and to prevent it from chilling in the nozzle. Means are provided for producing within the crucible a pressure of about 100 lb. per square inch to force the molten metal out through the casting nozzle and into the mold. (1,126,079, Jan. 26, 1915.)

Lining Furnaces by Cement Gun and Torch.—The necessity of keeping furnace walls in good repair, and the obvious difficulty and expense which attend the ordinary methods of doing this work, has led ALFRED SCHWARZ, of New York City, to devise a means of forming and repairing furnace walls in an improved manner. The apparatus required is similar to that used in cement work, the so-called cement gun, in combina-

tion with a high-temperature flame. In operation the ground refractory material to be used for the lining is projected through the gun at velocities ranging from 3000 to 15,000 ft. per minute. As the particles leave the gun they are forced onto the wall and embedded therein in a fused condition, due to the softening effect of the flame. The process may be used while the furnace is hot or cold. As the cement gun and torch are well-known machines, the invention lies in the process of forming or repairing walls of furnaces by projecting comminuted refractory material at a high velocity against the wall and subjecting the wall to a fusing temperature at the time and point of application. (1,125,741, Jan. 19, 1915.)

Another process of forming furnace walls and preventing their disintegration due to heat is patented by JOSEF HEMMER, of Veitsch, Austria-Hungary. Pieces of iron are mixed in the mortar, in which the bricks are laid. (1,123,874, Jan. 5, 1915.)

Chemical Engineering

Fixation of Atmospheric Nitrogen.—A patent by SAMUEL PEACOCK (assigned to the International Agricultural Corporation) relates to a new nitride process of the same general type as the Serpek process. The inventor starts with feldspar which is finely ground and mixed with carbon. He uses for every pound of alumina 0.75 lb. of carbon, for each pound of potash (K_2O) 0.3 lb. of carbon; and for each pound of silica 0.8 lb. of carbon. This mixture is heated in an electric furnace, and as the temperature rises to say 2500 deg. C., a flow of nitrogen gas is maintained through or over the mixture. There is stated to result the formation of a higher carbide of aluminium Al_4C_3 and of potassium carbide K_2C , and this is said to be followed by the formation of carbonitrides of aluminium and potassium, respectively; the following equations being given $Al_4C_3 + 3N_2 = Al_3N_2C_3N$, and $3K_2C + 3N_2 = K_3N_2C_3N$. Both of these carbo-nitrides are volatile at high temperatures employed, and may be conveniently sucked out of the furnace and collected in bag separators or forced into a digester. In the digester the carbo-nitrides are subjected "to the action of superheated steam at a pressure of say 5 to 7 atmospheres, whereupon the following reactions take place, producing alumina, potassium carbonate and ammonia: $Al_3N_2C_3N + 9H_2O = Al_2O_3 + 3CO_2 + 6NH_3$, $K_3N_2C_3N + 9H_2O = 3K_2CO_3 + 6NH_3$. Of course, more or less silicon carbo-nitride SiN_2C_3N will also form, but at the high temperature of the furnace charge, it will practically all dissociate and remain in the form of a carbide. By now cutting off the nitrogen and raising the temperature of the furnace to say 2800 deg. C., the well-known product siloxicon, Si_2C_2O , may be obtained, as well as other oxycarbides; and by still further increasing the temperature up to say 3500 deg. C., the lower silicon carbide SiC may be obtained. It will thus be seen that my invention takes advantage of the high temperature necessary to make siloxicon, or silicon carbide, to produce carbo-nitride, without an extra cost of energy, and that from these carbides alumina, potassium carbonate, and ammonia may be produced. Further, the alumina and potash are separated from the mineral and the nitrogen fixation occurs before the temperatures necessary for the formation of the silicon compounds are reached; so that when said last mentioned compounds are to be formed the proper proportions of silica are present in the charge. It therefore follows that the above by-products are obtained, without interfering with the regular process of making the said silicon compounds." (1,129,506, Feb. 23, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

The Consulting Metallurgist and Metallurgical Investigations is the title of a forceful and timely article by Mr. W. B. BLYTH, published in the *Proceedings* of the Australasian Institute of Mining Engineers, No. 16, 1914. The article relates to the work of the consulting metallurgist in the cyanidation of gold and silver ores, and gives many pertinent suggestions regarding the testing of ores, designing and operation of plants, and investigation of existing plants. In addition to technical data, the article contains much wholesome advice. A few of the important matters are here briefly reported.

The author points out the difficulty of interpreting probable commercial results from small scale tests, but adds that "common sense, resource and dependable apparatus are the most valuable assets in comparing work of this nature."

Attention is called to the necessity for co-operation between the mining, the mechanical and the metallurgical engineer, in order to get the best economic results and to safeguard the investigator in matters on which he is not expert. In order to avoid future misunderstanding with the directors of a company it is well to limit the anticipated extraction to a given tonnage, so that future overloading of the plant, with its attendant lowering of extraction, cannot be made to reflect on the investigator.

In testing for the treatment of raw sulphide ores and concentrates dry crushing will give faulty results for the following reasons:

- (a) That dry crushing and screening is positive crushing, and the softer particles of high specific gravity are not necessarily crushed finer than the hard particles of low specific gravity. Consequently, although screen tests may show that the whole product is fine enough, yet in reality the gangue particles are probably too fine and the sulphide not nearly fine enough. The percentage of colloids in a sample crushed wet to pass a 150-mesh screen is enormously in excess of that in the same sample crushed dry.
- (b) An excess of abraded iron is produced in dry crushing, and the heat generated expedites oxidation in sulphides that are liable to rapid oxidation—both disastrous factors, under certain conditions, to subsequent cyanide treatment.

It is pointed out that abraded iron is innocuous if the solution is kept alkaline with CaO and no heat be generated. Once oxidized, however, the iron precipitates ferrous hydroxide with lime, and ferrocyanide is formed. The resulting conditions are such that good results are impossible. Ferrocyanide in itself is harmless, but its presence suggests that poor conditions have existed or do exist. Graphite is without effect except that it acts like oil in the flotation process and surrounds mineral with a scum which prevents extraction. The effect of pyrrhotite is not clearly understood. In some cases it acts as a precipitant.

Much stress is laid on the preparation of the sample on which tests and assays are made. The metallurgical engineer is urged to know for himself the nature of underground conditions, the quality and quantity of ore, and the collection of the samples. "Expecting sharp criticism from mining engineers, perhaps few are competent to select, unaided, a representative sample from a mine for the purpose desired."

The investigation of the hardness of the ore is necessary in order to determine grinding conditions. The author's method of computing regrinding factors was outlined in this journal, August, 1914, page 537.

Discrepancies between laboratory and plant roasting are discussed at length. Time is believed by the author to be the most notable factor in these discrepancies. In a comparative test he found that whereas ore remained in a furnace for several hours, attaining its temperature gradually, a muffle roast in the laboratory is complete in

45 minutes. His apparatus and method for getting comparative results are as follows:

"A cast-iron dish 4 in. deep, divided into two compartments, is made to closely fit into an ordinary wind assay furnace fired with coke. The fire is started and the shaft filled with cold coke, well rammed. The cast-iron dish is then placed in position on top of the fire and the edges packed tight with small coke. A charge of the ore to be tested is placed in one compartment (1000 grm.), while a charge of an ore on which dry-crushing and cyaniding results are already proved is placed in the other. The draught is kept well back, and the heat gradually raised with constant rabbling. In about 30 min. sulphur should commence to come off, and this should all be off in two hours. After two hours the heat can be raised as much as possible, and finally the lid of the furnace is closed for about 10 min. Rabbling must be carried on carefully all the time, as any fritting precludes success. If subsequent cyaniding experiments on the ore (on which the process is proved) give plant results, then the results obtained on the new ore may be accepted as reliable. By this means the writer has obtained reliable results which have been borne out in the plant."

Amalgamation tests on a small scale cannot be relied upon, and inasmuch as amalgamation plays such a relatively unimportant part in cyanidation nowadays, the author prefers merely to amalgamate in a pan for the removal of coarse gold and not to indicate what saving can be made by that process.

Leaching tests usually give dependable results. They should be made in a high column, say, 6 ft., and aera-

work. The new producer has too much at stake to take any chances."

In making vacuum-filter capacity tests care must be taken to filter the product in exactly the same condition experimentally as it will be obtained in the plant. The question of replacement of pregnant solution with wash solutions is a criterion of the work. A good way to conduct these tests is to take a series of solution samples from the vacuum pump discharge every five minutes during the wash. When the assays are arranged in graphic form they show the replacement of gold solution by barren wash, and when two washes are used the replacement of barren solution by water is indicated.

Special attention is directed to the assay of slime residue and the probability that such assays will be faulty unless the greatest care is exercised. The losses which may occur in drying the sample, especially the losses of dissolved gold in the residue, are remarkable. This point was touched on at some length in this journal, February, 1915, page 119. The use of precipitants is advisable before drying and assaying. Cuprous chloride or Whitby's mixture (copper sulphate, sodium sulphite and sulphuric acid) are suitable precipitants.

In estimating working costs after having determined the economic solution of the extraction problem, the metallurgist should lay out the flow sheet in detail and estimate treatment costs. The type of plant required must be determined by sketching out in detail all the possible economic alterations. Then detailed treatment costs should be prepared, and a balance sheet made showing the net result of each alternative scheme. "Cost estimates can only be safely entrusted to experienced and conservative operators." Fixed and variable costs must be considered, especially the latter, as they vary with each individual ore.

Determination of Gold and Silver in Cyanide Solutions.—In the *Bulletin* of the American Institute of Mining Engineers for February, 1914, Mr. L. W. BAHNEY, of New Haven, Conn., presents a method for determining gold and silver in cyanide solutions, of which we present an abstract. Five assay tons of solution (146 cc.) is placed in a 250-cc. beaker. Add successively 20 cc. of a 20 per cent solution of lead acetate and 15 cc. concentrated hydrochloric acid. Then place a 1/4-in. rod of zinc in the beaker and boil the solution for five minutes. Fill with cold water; then decant about half, and again fill with cold water. Withdraw the zinc rod, freeing it from particles of lead sponge. Wash the sponge several times with water, press sponge together to remove water, decant and wash again. Place the sponge in a piece of sheet lead 2 in. square, fold and cupel. In case the sponge does not cohere in a single piece it may be filtered on a piece of lead foil formed into a cone and containing some test lead.

Copper

Oil-Fired Reverberatory Smelting at Nevada Consolidated Copper Co.—In a paper presented at the February meeting of the American Institute of Mining Engineers Mr. R. E. H. POMEROY gave some data on reverberatory copper smelting at McGill, Nevada. The furnace is 132 ft. long with an average width of 18 ft. 10 in. at the skim-line level. It is equipped with two 400-B.hp Stirling waste-heat boilers. The fuel is California crude petroleum of 16.5 deg. B. sp. gr., and with a flash point of 199 deg. Fahr. It is heated to 200

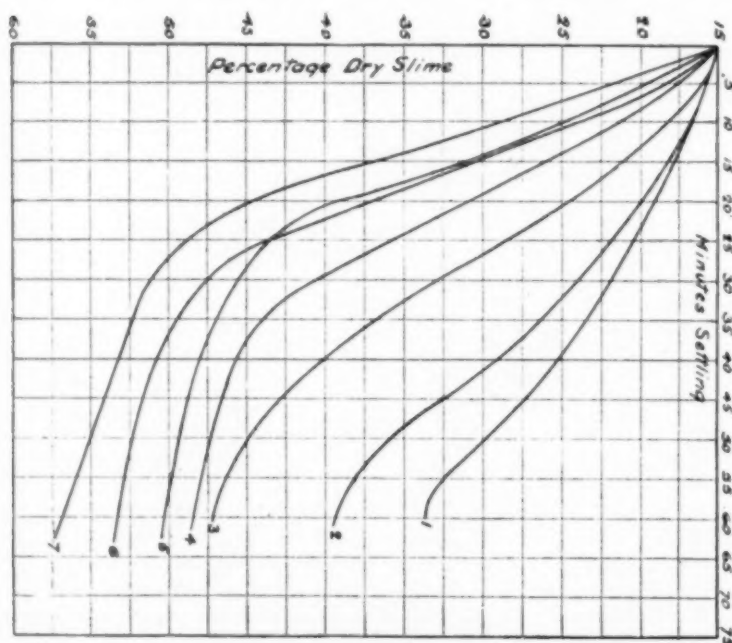


FIG. 1—SLIME SETTLEMENT CHART

tion of the sand and solutions should be attempted.

The determination of the slime-settling rate is an important matter. The author has elaborated a standard slime-settlement chart, shown in Fig. 1, based on tests conducted as follows:

Two 1000 cc measuring flasks were obtained of similar height (15 in.). A 15 per cent pulp of the slime to be tested was introduced into the flask. The pulping medium tested 0.05 per cent KCy and 0.013 per cent CaO; 15 per cent was determined on as representing a fair plant thickness. The test was conducted on the sampled slime from a number of different mines which had efficient settlement plant already installed. The settlement test was conducted in each case under identical conditions with regard to the determining factors, but the particular mine water was used in each case. There are mine waters varying from 0.1 per cent to 26 per cent of solids in Western Australia, and this is a factor of great importance in making settlement tests. Settlement was allowed for one hour in each case, and two tests were conducted—one in the alkaline cyanide solution already described, and the other in the ordinary non-alkaline mine water. The diagram (Fig. 1) shows the tests conducted in the alkaline solution only. The diagram is of considerable value in designing plants, as, knowing the settlement area for a given tonnage of slime on the mines illustrated on the diagram, it is only necessary to compare a settlement test conducted under similar conditions to arrive at the settlement area required to do definite work on the ore under examination."

Referring to new processes designed to supplant proved methods, the author wisely observes: "Let the old-established producing mine do the experimental

TABLE I.—ANALYSES

Material	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Concentrates roasted	6.48	28.4	27.0	...	5.2	28.4
Cold secondaries	9.37	19.9	43.4	...	3.4	8.4
Hot converter slag	2.01	27.2	46.2	...	4.5	1.2
Pettling slimes	3.32	65.8	7.3	...	8.3	7.6
Lime rock	...	2.1	0.8	51.1	0.8	...
Roaster flue dust	5.85	40.4	15.2	0.7	6.6	9.32
Reverberatory matte	27.46	0.4	40.8	...	0.5	27.46
Reverberatory slag	0.298	42.2	28.4	9.5	6.8	0.4

TABLE II.—SCREEN ANALYSIS OF CONCENTRATES ROASTED

Mesh	+30	+40	+60	+80	+100	+150	+200	-200	Average
Weight, per cent	9.7	7.4	13.4	10.4	11.9	13.5	9.6	24.1	...
Copper, per cent	3.23	4.33	6.16	7.44	7.28	7.60	7.27	6.88	6.48

nersville blower at 40 oz. Air supplied at the burners amounts to about 10 per cent of that required for complete combustion, the balance entering through the burner openings in the firing wall. Combustion is practically complete, less than 0.5 per cent CO existing in the gases at the front of the furnace. Evaporation at the waste-heat boilers was 4.81 lb. water per pound of oil burned.

Plan and section of the furnace are shown in Fig. 2, and in Fig. 3 is given a graphical representation of the side-door temperatures at different intervals after charging. Tables I to IV inclusive give interesting data.

The vital points in reverberatory furnace smelting at McGill are summarized on top of page 254.

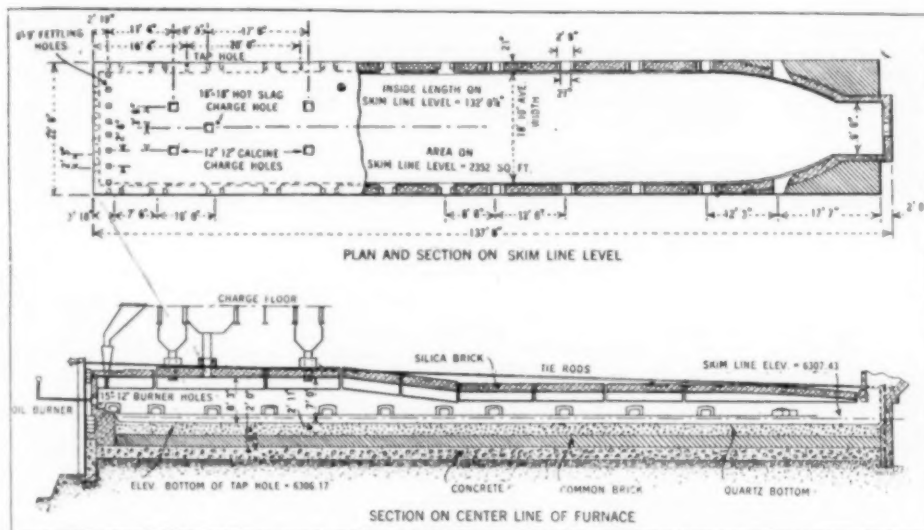


FIG. 2—REVERBERATORY FURNACE NO. 2 AT MCGILL

TABLE III.—PERFORMANCE OF FURNACE

Month, 1914	Furnace Days	Total Charge per Furnace Day—Tons	Daily Tons per 100 Sq. Ft. Hearth Area—Total Charge	Solid Charge per Furnace Day—Tons	Daily Tons per 100 Sq. Ft. Hearth Area—Solid Charge	Oil Fired per Furnace Day—Bbls.	Gross Oil Ratio Bbl. per Ton—Total Charge	Gross Oil Ratio Bbl. per Ton—Solid Charge	14-lb. Basis Waste-Heat Recovery, Per Cent	Net Oil Ratio Bbl. per Ton—Total Charge	Net Oil Ratio Bbl. per Ton—Solid Charge
April	30.0	694	29.53	609	25.91	371	0.53	0.61	32.48	0.358	0.412
May	30.8	665	28.29	581	24.72	384	0.58	0.66	34.99	0.377	0.429
June	30.0	659	28.03	582	24.76	372	0.56	0.64	36.43	0.356	0.407
July	31.0	721	30.68	628	26.72	415	0.58	0.66	33.51	0.386	0.439
Average	30.4	685	29.15	600	25.53	385	0.562	0.642	34.35	0.370	0.421

NOTE.—The above period does not cover a complete campaign.

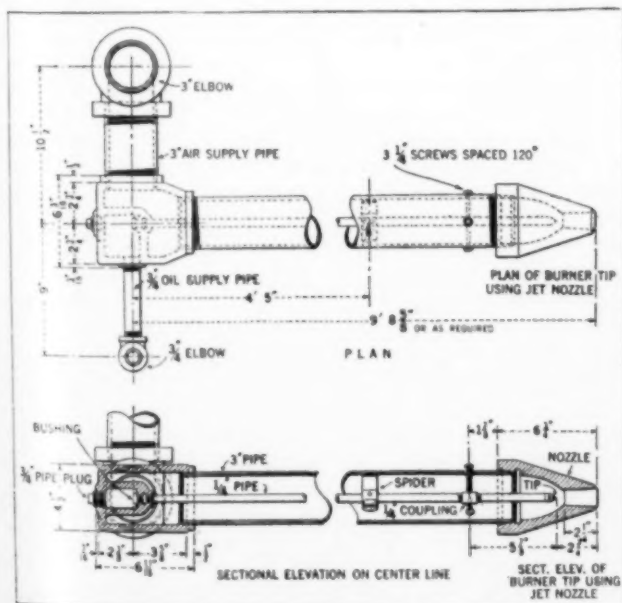


FIG. 3—LOW-PRESSURE OIL BURNERS, STEPTOE TYPE

deg. Fahr. before going to the burners. Feed is by gravity (34 lb. static pressure) to low-pressure blast burners shown in Fig. 3. Blast is supplied from a Con-

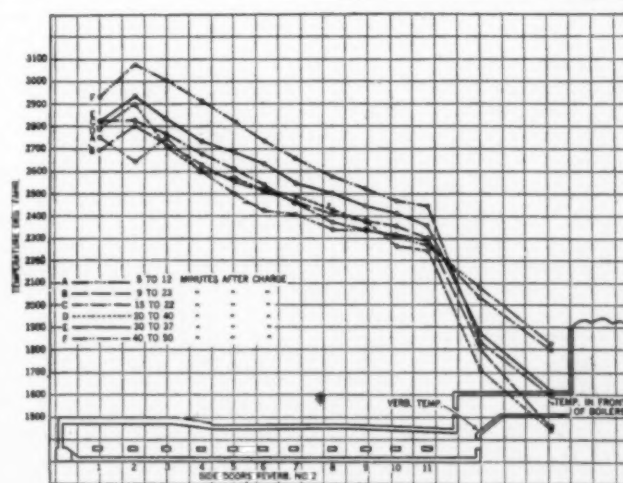


FIG. 4—CURVES SHOWING SIDE-DOOR TEMPERATURES OF REVERBERATORY NO. 2 TAKEN AT DIFFERENT INTERVALS AFTER CHARGING

TABLE IV.—PERCENTAGE ANALYSIS OF CHARGE SMELTED

Month, 1914	Calclines	Cold Sec-ondaries	Hot Con-verter	Hot Con-verter Slag	Fettling	Lime Rock	Roaster Flue Dust
April	59.3	8.0	12.2	4.6	12.9	3.0	...
May	58.7	8.0	12.6	4.8	12.3	3.6	...
June	63.4	6.6	11.7	5.4	12.1	0.8	...
July	58.4	7.7	12.9	5.3	13.0	2.7	...
Average	59.9	7.6	12.4	4.9	12.7	2.5	...

Factors affecting efficient combustion of the fuel:

1. The use of a burner to give a proper atomization of the oil so as to obtain a long uniform flame without overheating any portion of the furnace.

2. Regulation of the draft so as to furnish the proper mixture of gases for complete combustion in the furnace.

Factors affecting the operation of the furnace proper:

1. Careful preparation of the charge by adequate mixing of all ingredients before charging.

2. Addition of enough lime rock, preferably coarse, to produce an active boiling in the furnace.

3. Maintaining a deep bath of molten matte to equalize and distribute the heat over the whole of the hearth.

4. Frequent skimming so as to carry only a thin layer of slag over the matte bath.

5. Operating the furnace for the best smelting conditions, ignoring the waste-heat boilers as factors in the power supply.

Factors affecting the life of the furnace:

1. The furnace roof set high over the hottest portion of the hearth.

2. Frequent fettling to protect the side walls.

3. Frequent charging and active charge mixtures to avoid floater and blanket formation requiring excessive firing.

Metallurgical and Chemical Engineering in Great Britain

(By our London correspondent)

Birmingham Section, Institute of Metals

Mr. T. J. Baker, Sr.'s paper on "Bronzing Processes Suitable for Brass and Copper" was read on Jan. 26, and dealt with steel-bronzing, with possibilities of variation in coloring on the same object, by stopping out, or employing an intermediate coppering bath for the brass; also the production of black, deep blue and antique effects. The variety of colors which can be obtained on brass-work, such as gold, crimson, purple, blue and lavender, though not employed commercially, suggest a field worthy of investigation by the producers of jewelry.

Refractory Materials and the War

In a contribution to the *Journal* of the Royal Society of Arts, Mr. Alfred B. Searle points out that the importation of bricks for building coke ovens and other furnaces from Belgium has ceased, and that consequently efforts are being made in this country to bring fire-bricks up to the specification required by the continental builders.

Similarly retorts for the manufacture of coal gas are not now obtained from Germany. The relative values here appear to be more indeterminate, as some German engineers imported British retorts, and vice versa.

Iron and Steel Institute Dinner

The annual meeting of the Iron and Steel Institute will be held by kind permission at the Institution of Civil Engineers on Thursday and Friday, May 13 and 14, 1915. The date for the annual dinner has been provisionally given as May 13 but this will be the subject of a future announcement.

Scottish Oil Trade

A Scotch company have erected a plant at Addrewell for operation of a German patent process, the rights of which were acquired last spring for the conversion of oil products into commercial materials.

Institute of Industry and Commerce

The interests of chemical manufacturers in this country are receiving the attention of a central committee which meets early in February at the offices of the Institute of Industry and Commerce, Strand. A preliminary meeting has already been held.

Platinum in Russia

The British vice-consul at Ekatermburg gives some interesting notes on the platinum position. The present situation has, apparently, resulted in an interruption to the regular export trade, due to continental buyers not taking up contracts, and there should therefore be temporarily more platinum on the market than usual.

Heating of Mines

The heat in deep mines was treated of by Professor Cadinaw, D.Sc., in his lecture at Ashby-de-la-Zouch on Jan. 23. He took the sources of heat under three heads: (1) Heat due to rock temperature; (2) heat due to compression of the air, and (3) heat due to oxidation. Heat could not be modified by the introduction of moisture in deep mines, as this was detrimental to workmen, and it was also imperative in deep work to keep the air dry. For the prevention of oxidation the following means appeared the most effective: (1) Lining the roadways with non-oxidizable material; (2) measures for preventing the spreading of coal dust, and (3) complete re-filling of spaces left after extraction of coal. The lecturer was very optimistic as to the prevention of explosions in connection with coal dust.

Coal Prices

The present high level of coal prices in this country is attributable to a variety of causes working together: limited production, due in some measure to absence of men at the war, and also to the high remuneration permitting of very short hours being worked by the miners being among the chief. So far as the southern centers of population are concerned, especially London, the transport element comes certainly into consideration, and certainly has its influence on the price. The ultimate tendency of the kind of squeeze which the major portion of the community are experiencing, must be in the direction of nationalization of the more important national assets to such an extent as to avoid leaving the country entirely to the direction of a limited number of owners or an organized privileged class of operators.

Peat Fuel

The high price of coal has turned the general attention to other fuels. The possibility of utilizing peat in a water-gas process was originally suggested by Dr. L. Mond, and two plants acting on this principal are actually working in Italy, at Orentano and Codigoro. As described by Prof. Ugo Rossi, these consist of a turret-shaped oven into which the dried and broken peat is thrown. Steam and hot air are admitted by means of jets, and the water in contact with the incandescent mass produces Mond gas, which collects at the top of the oven.

The gas is then subjected to two purifying processes, and is ultimately used for power purposes. The purifying process involves the production of sulphate of ammonia, a peat containing 2.5 per cent of nitrogen yielding about 1½ cwt. of sulphate of ammonia to the ton.

Oil

If the civilization of the future is to follow the oil deposits in the same way as that of the present has adhered (with the usual marked exception) to the coal fields, there is still considerable prospect of improved circumstances for the world's population. While recent additions to the oil areas in Russia can hardly be said to have proved their value so far, the proximity of Roumania and Galicia may be looked to to remedy any existing deficiency. Turkey contains promising districts for investigation, which would be worthy of the attention they will probably ultimately attract. In Africa, Algeria and Egypt have both been the subject of recent exploration in this direction, and a number of wells were completed in the latter. Taking, in fact, the Eastern map of Europe, as well as the adjacent portions of the map of Africa, it appears that civilization, when not already established on the oil country, is satisfactorily progressing toward it.

Copper Cyanide Plating Solutions*

BY DR. MAX C. WEBER

I have chosen as a subject the working of a copper bath, as this is by far the most extensively used and also the most instructive solution.

There are three things which are necessary for the deposition of metal—current, electrode and electrolyte. As the electrolyte or plating solution is the most important, I will confine myself to this item.

The object of employing cyanide solutions for the deposition of copper is to be sought in the fact that in such solutions iron does not replace copper, notwithstanding their places in the electrolytic series, a phenomenon which is due to the complexity of the salt in which the copper is present. The complex salt, which makes this feasible, is the double cyanide or sodium copper cyanide, the anion of which is Na , the cation CuCy_2 ; that is, by the action of the electric current, Na travels toward the cathode, CuCy_2 toward the anode. In other words, copper is not present in an ionized stage. Under proper current conditions, *i. e.*, not too high current density and a suitable concentration of the solution, Na is not discharged at the cathode, but reacts with an undissociated part of NaCuCy_2 , as per the following equation:



thus showing that the deposition of copper is a secondary reaction, and that free cyanide is formed. On the anode, the anion CuCy_2 combines with the copper of the electrode, forming cuprous cyanide $\text{CuCy}_2 + \text{Cu} = 2\text{CuCy}$.

Cuprous cyanide is insoluble in water, but soluble in cyanide solution, and for this purpose the free cyanide generated at the cathode is required. Supposing we have proper conditions—low current density on both electrodes—enough free cyanide is produced on the cathode in order to keep in solution the cuprous cyanide formed on the anode. As the free cyanide of the cathode is really needed on the anode for dissolving purposes, and as in a still solution the mixing velocity is very slow, stirring and warming of the electrolytic bath would expedite this matter considerably and bring the bath very near to an ideal stage. However, warm and agitated solutions require a more careful observation on account of which these two items have not as yet been paid the attention they actually deserve.

If too high a current density is used on the cathode, not all the Na ions act reducing on the sodium copper cyanide, but are partly discharged, forming sodium hydrate and hydrogen in connection with the water of the bath:



This reaction accounts for the development of hydrogen or gasing at the cathode. It means that less copper is deposited per ampere hour and not sufficient free cyanide formed in order to keep the anode clean. Therefore, the solution necessitates the addition of sodium cyanide, otherwise the anode becomes coated and the passage of the current is interrupted. Too high a current density on the anode leads to the same result; covering of the electrode with an insulating film of cupri-cupro cyanide.

In regard to current density, it must be borne in mind that warmed and agitated solutions can be worked with a higher current density than cold ones, and that a density of approximately 30 amperes per square foot is quite feasible without yielding a burned and blistered deposit.

Another feature which is quite interesting is the amount of metal deposited per ampere hour. In a cop-

per cyanide solution which contains the metal in the cuprous state, the same number of ampere hours should yield twice as much metal as in an acid bath, providing, of course, all the favorable conditions are prevailing, *i. e.*, a strong solution, warmed and agitated, worked with a minimum amount of free cyanide at a low current density. As, however, common plating solutions are worked on nearly the contrary conditions, the relative amount obtained from a cyanide bath is much lower. How much lower depends entirely on the relative conditions, and only one feature should be emphasized, which has been mentioned above: that the more hydrogen develops on the cathode, so much lower is the percentage of the metal deposited per ampere hour. A low current density results in a high weight of the metal deposited per ampere hour, while the deposition is slow. A high current density yields a lower weight proportionately per ampere hour, but consuming less time for a certain weight of metal deposited, resulting in a greater deposition of metal per hour.

Furthermore, cyanide solutions yield a finer, more homogeneous texture and brighter metal film than the acid baths on account of the secondary copper deposition and because hydrogen may develop more freely on the cathode in such a solution without fear of burning or blistering the deposit.

These few remarks give an idea how complicated the reactions in a plating solution are, and that it requires skill and experience to procure a satisfactory deposit.

The first part of this paper has shown that the constituent which is essential in a copper cyanide bath is the double salt, sodium copper cyanide, consisting of copper cyanide and sodium cyanide, which is easily formed by adding the necessary amounts of each chemical to water. A high-grade sodium cyanide has been obtainable for quite a number of years, but copper cyanide could only be procured at prices which made its use prohibitive for technical purposes.

For this reason many salts—one might call them subterfuges—have been used which were intended to substitute copper cyanide and form the same when brought together with cyanide solution. One should bear in mind that whatever copper salt is brought together with cyanide solution, the final compound is the double salt, sodium copper cyanide. Another fact which should not be lost sight of is that one chemical can replace another only to the extent of the requisite elements, and that by the reaction of two such salts, always a by-product is formed which contaminates the compound desired.

This is the case with the copper cyanide. Copper carbonate, copper sulphate, copper acetate, cupri-cupro sulphite have been employed in order to form copper cyanide in connection with sodium cyanide and water. That by these reactions an inert by-product consisting of sodium sulphate or sodium sulphite or sodium acetate or sodium carbonate is formed to a high percentage every one was aware of, but took it for granted as the product necessary, *i. e.*, copper cyanide was not obtainable commercially.

When using copper carbonate, which is really basic copper sulphate containing a small percentage of carbonate, according to the temperature at which it is precipitated, approximately one-half pound of inert matter is formed for every pound of copper carbonate, being composed of sulphates and carbonates. By the use of copper acetate, or cupri-cupro sulphite this inert matter is still further increased, and for each pound of the compounds used, from nine to ten ounces inert salts are produced. These salts accumulate in the bath more and more with every addition of the respective copper salt, and finally yield such a dense solution, which being overloaded with these waste compounds cannot be worked

*A paper presented before the Lewis Institute, Chicago, Ill.

in a satisfactory manner any longer, the plated articles being blistered and the solutions are of necessity discarded.

The reason for this is that a bath of this kind has a relatively low metal concentration and a much higher one of the inert salts. As a rule, the electric current deposits the metal easiest to discharge, which in this case is the alkali metal. Therefore, as the current density increases an excess of hydrogen is generated, which causes burning, and the current output drops considerably.

After considering this crude method of forming copper cyanide one should remember that the copper in a cyanide plating solution is in the cupro stage, while copper carbonate, copper sulphate, copper acetate are cupri salts, and cupri-cupro sulphite is a mixture of both. This means these salts must be first reduced to the cupro state before they are fit for plating. This reduction is executed at the cost of the sodium cyanide which is actually intended for bringing the copper metal into solution only. Further, neutral copper salts as copper acetate, copper sulphate and cupri sulphite, when brought in contact with cyanide solutions, form cupri cyanide first, which, being an unstable compound, decomposes into cupro cyanide and cyanogen, which latter escapes into the air, and on account of its highly poisonous character is most detrimental to the health of the plater.

Taking into consideration all the disadvantages resulting from the present method for producing a plating solution, every progressive plater should greet with joy the fact that a chemically pure cupro cyanide is now on the market at a price making its use more economical than that of any other copper salt which has been accomplished by new manufacturing methods worked out by the author of this article.

Cupro cyanide contains nothing but the ingredients necessary in a plating solution—copper and cyanogen—so that by dissolving it in cyanide solution no inert, unnecessary products are added. This enables the plater to have perfect control of his solutions at all times, as whenever metal is needed he adds it in the form of copper cyanide, and, when cyanide is needed, sodium cyanide, thus simplifying matters. On account of its high percentage of metal—it contains 70 per cent pure copper, the rest being cyanogen—solutions highly concentrated in metal can be worked at a relatively low specific gravity. This is a further advantage, as a bath low in density is much more easily controlled than a very concentrated one.

Copper cyanide being a cupro salt, does not consume any cyanide in order to be transferred to the cupro stage, and because of its being a cyanide itself it requires less sodium cyanide than any other copper salt to yield the double salt sodium copper cyanide, the essential constituent of a plating solution. This fact points out a more economical method for producing a plating solution. In other words, it saves money. When one buys a metal salt for plating one should not forget that it is not the price of the metal in the salt itself which constitutes the economy of the salt, but the price at which the metal is put into solution as a double cyanide. It is this economy of the copper cyanide combined with its high technical qualities which makes copper cyanide superior to any other plating salt.

The figures in Table I give a comparison of plating solutions produced with different copper salts and are the results of actual tests. The metal contents of the solutions are the same in Table I.

After continuous operations for two hours it was found that while the solution made up with copper cyanide remained almost constant—that is, the relative proportions of metal and cyanide were practically the

TABLE I

<i>Copper cyanide, 70 per cent copper:</i>		
100 lbs. copper cyanide at 42c. per lb.	\$42.00	
100 lbs. sodium cyanide, 129 per cent, at 22c. per lb.	22.00	\$64.00
<i>Copper carbonate, 50 per cent copper:</i>		
140 lbs. copper carbonate at 14c. per lb.	\$19.60	
239 lbs. sodium cyanide, 129 per cent, at 22c. per lb.	52.58	\$72.18
<i>Cupri-Cupro sulphite, termed red copper compound—40 per cent copper:</i>		
175 lbs. red copper compound at 30c. per lb.	\$52.50	
160 lbs. sodium cyanide, 129 per cent, at 22c. per lb.	35.20	\$87.70
<i>Copper acetate, 31 per cent copper:</i>		
220 lbs. copper acetate at 25c. per lb.	\$44.00	
193 lbs. sodium cyanide, 129 per cent, at 22c. per lb.	42.46	\$86.46

same—the solution made up with the other salts became unbalanced. The anodes coating over requiring further additions of cyanide, showing once more that solutions made up with chemically pure copper cyanide gave maximum efficiency.

As so-called copper carbonate was the most extensively used, I gave this solution special attention and found, after considerable experimenting, that in order to obtain a solution with sufficient free cyanide to obtain a fairly balanced solution the following proportions were necessary:

140 lbs. copper carbonate at 14c. per lb.	\$19.60
280 lbs. sodium cyanide, 129 per cent., at 22c. per lb.	61.60
	\$81.20

These comparative figures vindicate once more one of the most important rules in chemistry—that pure materials not only give the greatest efficiency, but are the most economical.

In the present time, which is distinguished by the endeavor to obtain an end as simply and as economically as possible, where everything is standardized in order to obtain the best results at the lowest cost, no far-sighted man can dispute the fact that copper cyanide brings this desired standardization to the plating industry which means utmost economy and high results.

Blowers and Fans.—The Clarage Foundry & Mfg. Co. of Kalamazoo, Mich., has recently published a catalog describing Clarage type C.I., cast-iron volume blowers. These fans are built in four sizes, 5, 6, 7 and 9, and the number in each case is the same as the diameter in inches in the suction or outlet connection. The housing or fan case is cast in one piece, and is supported by cast-iron side plates. These plates are larger than the fan wheel, and by merely taking out eight cap screws and removing the plate the wheel may be withdrawn from the housing. This same feature makes these fans adjustable and reversible, as any one of seven different directions of discharge may be secured, and the arm supporting the bearing may be placed on either side of the fan. Although furnished regularly as single inlet exhaust fans with a collar for the suction pipe or intake side it is possible by removing the collar and plate to use these fans or blowers having two inlets, and thus obtain the resulting high efficiency. The special dust-proof, oil-tight, enclosed bearings are features of importance in dusty installations, and the large supply of oil assures a cool running machine. To invert the fans the only change necessary is to interchange the positions of the oil supply pipe and the plug in the bearing. The type C.I. fans, as single-inlet exhausters, may be used to remove smoke, chemical vapors, or fumes from forge fires, stoves, ranges, vats or kettles, exhausting air in small ventilating installations for toilet rooms, telephone booths, etc., or they may be used to convey light material, such as removing dust from emery wheels, or tumbling barrels or shavings from wood-working machines. As double inlet blowers the type C.I. fans furnish blast for forge-draft fans for small boiler plants.

Refractories of the Rocky Mountain Region, and Some of Their Products

BY J. C. BAILAR

Before using a new piece of chemical porcelain ware the chemist has long been accustomed to remove a stamp bearing the word "Germany," and coupled with this habit of years has come the fixed belief in the minds of many people that such ware cannot be made in the United States. The same idea once prevailed with regard to fire-clay goods. The first smelters in the Rocky Mountain region used fire-brick made in England; that assayers also imported muffles, crucibles and scorifiers. It is possible that some American ware was used, but where the fire was hottest no brick was used that did not bear the then magic word "Battersea." Fortunately for the mining industry of this region, the first smelters were erected near a deposit of excellent fire-clay. This deposit marks the eastern boundary of the Rocky Mountains in Colorado and has been opened



FIG. 1—HEROLD CHINA AND POTTERY CO., GOLDEN, COLO.

in many places for a distance of approximately 250 miles. It is accompanied by large bodies of shale and plastic clay suitable for building brick, terra cotta, roofing tile, sewer pipe and the cheaper grades of pottery. In the nearby hills are found quartz and feldspar in abundance. There is enough of each of these to supply raw material for ceramic industries for several generations.

Superior Quality of the Fire-Clay

Tests made by the United States Geological Survey and others show the fire-clay to be one of the best known; but fifty years of practical use had already proved that. The chemical characteristics of some of the clays are shown in Table I. Numbers 1, 2, 3 and 4 are Golden fire-clays; No. 5 is a red-burning plastic clay from Golden, and No. 6 represents an average of fifty paving-brick shales. The analyses are from sources of undoubted reliability.

TABLE I
Analyses of Colorado Clays and Shales

Number	1	2	3	4	5	6
SiO ₂	50.35	45.99	46.61	56.41	60.60	56.00
Al ₂ O ₃	34.44	36.94	37.20	26.37	18.86	22.50
FeO	0.75	0.75	0.15	0.00	6.70	6.70
MgO	trace	0.26	0.25	0.20	1.50	1.40
CaO	0.00	0.23	0.44	0.29	2.70	1.20
Na ₂ O	0.10	0.45	1.23	1.55	....	3.70
K ₂ O	0.48	0.48	1.23	1.55	....	3.70
Ignition loss	13.88	14.13	13.65	14.66	9.32	7.00

The fire-brick made from the clay deposits in this region probably were produced in Golden, Colorado, in the early sixties. They were molded by hand and reshaped by means of a hand press. This method has not been entirely abandoned, though machines are now used for the greater part of the work.

Early in its history the brick industry was enlarged to include the manufacture of assayers' supplies. This department of the work has grown until the Colorado-

made assay crucible is known not only from Klondyke to Cape Horn, but has crossed the ocean seeking wider fields of usefulness. Certainly the name "Battersea," once so potent in the assayer's mind, has taken its proper place among the historical relics in Colorado. At the present time two companies are engaged in the manufacture of assay goods on a large scale. The Denver Fire Clay Company and the Mine & Smelter Supply Company both have factories in Denver, bringing the clays from the beds at Golden. The excellence of the products arises, of course, not only from the chemical nature of the clay, but from its physical characteristics as well. And added to these natural advantages in the raw material must be credited the long and expensive experimentation that the producers have conducted in order to determine the proper mixtures, methods of handling, tempering, molding and burning. These latter constitute the secrets of the trade, which are closely guarded in the clay-working industries.

Good sewer pipe and pottery also are being made from the Golden clays, several Denver firms being engaged in this line of work.

Fire-Proof Porcelain Ware

It has long been known that fire-proof goods of a finer grade than bricks and crucibles could be made from the Golden clays. In the fall of 1909 Mr. John J. Herold went to Golden to investigate the possibilities of making cooking utensils. While carrying on these investigations, Mr. Herold was compelled to make ornamental ware to pay expenses, and for nearly a year he was the only workman in his plant. Finally, however, he succeeded in interesting local capital and the Herold China & Pottery Company was organized, with Mr. Adolph Coors, president, and Mr. Adolph Coors, Jr., manager. The factory was greatly enlarged, as shown in Fig. 1, and an additional kiln has been built since the picture was taken. At present fifty people are employed.

About the time the company was organized a few casseroles and evaporating dishes were made and put to practical use in chemical laboratories with fairly good results. Later, when time could be spared from the regular work of the plant, several small lots were made and tested. Each lot was of a different mixture, and consequently there was no uniformity, each was a separate experiment. Every piece made showed excellent resistance to acids and alkalies, and some of the mixtures withstood alternate heating and cooling remarkably well. In fact some lots were superior to the best imported ware, when the two were used in the laboratory side by side.

Chemical Laboratory Ware

Until recently no chemical ware was made except these experimental lots, as the company devoted all its energies to the manufacture of cooking utensils. Now, however, the line of chemical ware is well established, and includes evaporating dishes, casseroles, porcelain crucibles, spatulas, mortars, glazed and unglazed tubes, and in fact everything that the chemist may require. Some battery cells made for the refinery of the United States mint in Denver last 50 per cent longer than the Royal Berlin cells that had been previously used. These products of the Herold factory have been duly investigated by chemical supply houses which have offered to contract for the entire output. It is understood, however, that the manufacturers prefer not to make such a contract, but sell in the open market. This factory has demonstrated beyond question to the writer that we can produce our own chemical porcelain ware in this country, and it does not require an optimist to predict that, with reasonable economic conditions, the stamp "Made

in Germany," so common on chemical porcelain, will gradually disappear.

Enameled Brick

These notes on the manufacture of refractories in the Rocky Mountain region would not be complete without mention of the product of the Sanitary Brick Company, of Golden. This company makes a high-grade enameled brick for both interior and exterior work. The process of manufacture is very different from the one generally used. The bricks are made by the stiff-mud process, and by an ingenious device the enamel is put on by the same machine. When somewhat dry, the enameled face is dipped into the glaze, and when the drying is complete the bricks are burned not in saggers or muffle kilns, but in common down-draft kilns such as are used in the manufacture of building brick. The enamel is about $\frac{1}{8}$ in. thick and is united to the body just as the glaze is united to a dinner plate. No line of cleavage can be found between the body and enamel when the brick is broken. It is scarcely necessary to say that to make and enamel ware in one operation, glaze the ware while green and complete it in one burn is not the usual procedure. These bricks will be used for part of the interior finish of the new Union Depot and Post Office now being built in Denver.

Golden, Colo.

Regulation of Electrotyping Solutions

The Bureau of Standards has started an investigation of electrotyping problems and the first result is Circular No. 52, just issued and entitled "Regulation of Electrotyping Solutions." The Bureau is not yet able to make definite recommendations regarding the best composition of solutions to be employed for any given method of operation for either copper or nickel electrotyping.

The circular first discusses the expression of the density of a solution either in degrees Beaume or by its specific gravity and gives two conversion tables. As to the composition of solutions it is said that in view of the almost universal use of the metric system in chemical analysis and other scientific work, preference will be given to the metric system in expressing the composition of the solutions. Since, however, the ordinary United States units are generally employed in electrotyping and similar commercial work, the values will also be expressed in such units. In making such calculations the following values and equivalents will be employed:

- One avoirdupois pound = 454 grams.
- One avoirdupois ounce = 28.35 grams.
- One United States liquid gallon = 231 cu. in.
- One United States liquid gallon = 3.785 liters.
- One liter = 1000 cc.
- One liter of water weighs 1000 grams.

From these values the following simple rules may be derived:

(a) To determine the approximate capacity of the vats in gallons, divide the cubical contents in cubic inches (up to the height of the solution) by 231.

(b) To convert grams per liter (g/l) to ounces per gallon (oz./gal.), multiply by 0.134; or divide by 7.5. Thus 50 g/l is equal to $50 \times 0.134 = 6.7$ oz./gal.

(c) To convert grams per liter to percentage by weight divide the grams per liter by ten times the specific gravity of the solution. Thus for a solution with a specific gravity of 1.15, 50 g/l is equal to

$$\frac{50}{10 \times 1.15} = \frac{50}{11.5} = 4.3 \text{ per cent.}$$

The portion of the circular which deals with regulation of the copper solution we give in full as follows.

Copper Solutions

1—GENERAL INFORMATION

The solutions usually employed for copper electrotyping contain, in addition to water, only copper sulphate and sulphuric acid. Since these substances and also the anode copper are usually fairly pure, there is no marked tendency for impurities to accumulate in the solution. The principal changes taking place in the composition of such solutions are due to two causes, (1) mechanical loss of the solution adhering to the "cases" (cathodes) when removed from the vats, and (2) solution of a greater amount of copper from the anodes than is deposited on the cathodes. The first factor would in itself

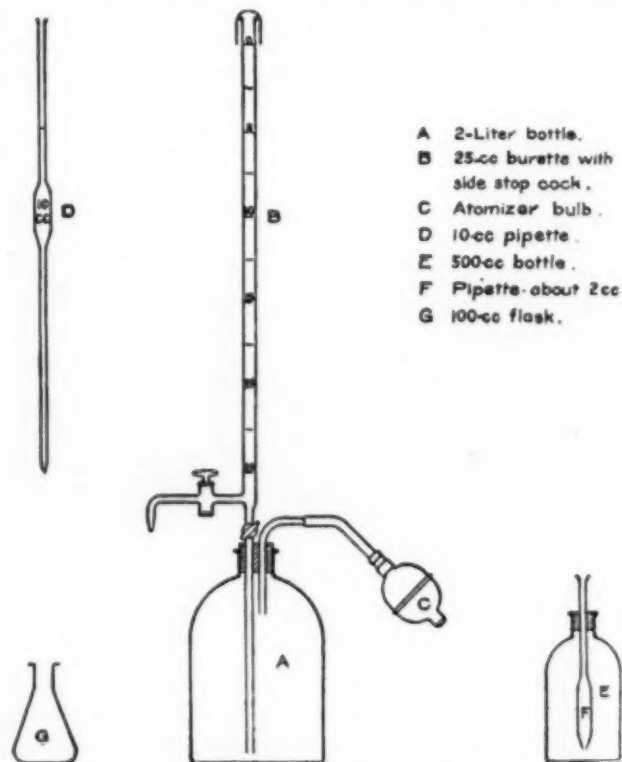


FIG. 1—APPARATUS FOR TESTING ACIDITY

cause a decrease in the density of the solutions, if, as is customary, the level of the latter is maintained approximately constant. (Water is added to the vats at intervals in order to replace that lost by evaporation.) The second action will cause a decrease in the acidity and an increase in the density of the solutions, owing to a consumption of sulphuric acid with the production of a corresponding amount of copper sulphate. In all cases thus far observed the latter effect is predominant. The exact causes of this consumption of acid and the best methods of reducing or eliminating it are now the subjects of investigation by the bureau.

In general it is necessary at intervals to determine and correct the composition of the solutions. The mere determination of the density of such solutions, whether with Beaume or specific-gravity hydrometer, is not sufficient to fix their composition. If, however, the density of the solutions and also the amount of free sulphuric acid present are determined, the composition is fixed. Thus, for example, a solution with a specific gravity of 1.16 (20 deg. Beaume) and containing 45 grams per liter (6 oz. per gallon) of free sulphuric acid has a perfectly definite and reproducible composition. The above figures do not, to be sure, indicate the amount of copper sulphate present in such a solution, but this is of no consequence to an electrotyper except when he is

preparing a new solution. For such cases tables showing the amount of copper sulphate required to produce solutions of any desired density, with any specified acid content, would be desirable, and will probably be prepared.

The bureau is not yet able to recommend any composition of the solutions as best adapted to any given conditions of operation. In various commercial solutions thus far tested the specific gravity ranges from 1.12 (15.5 deg. Beaume) to 1.20 (24.2 deg. Beaume) and the acidity from 25 g/l (3.3 oz./gal.) to 90 g/l (12 oz./gal.). In general the lower the voltage employed the more acid is required to produce a given current strength and rate of deposition, and vice versa. For the present, each operator should find a composition of solution which will give him satisfactory results under his conditions, and maintain it as nearly constant as possible by adjusting the density and acidity of the solutions at regular intervals (e.g., once a week) by the methods described in the following sections.

2—DENSITY

Before testing the solutions they should always be adjusted to the normal level of the vats by the addition of water if necessary, and thoroughly mixed. The hydrometer should always be read in the same way, preferably by floating it in a glass jar or cylinder containing the solution. By placing the eye slightly below the level of the solution, and then gradually raising the eye, the surface, first seen as an ellipse, becomes a straight line, the intersection of which with the hydrometer scale should be taken as the reading of the hydrometer. For practical purposes, and especially for comparison, the readings will usually be sufficiently accurate if made by observing the hydrometer scale above the surface of the liquid. The density should always be taken at approximately the same temperature, preferably 60 deg. F.

Having determined the density of the solution (which will usually be found to be higher than is desired), it may be adjusted to the desired density by the following method, based on the assumption that the excess density of the solution (above that of water) is approximately proportional to the content of the dissolved substances.

(a) *Specific Gravity*.—If a specific-gravity hydrometer is employed, divide the difference between the observed and desired specific gravities by the difference between the observed specific gravity and the specific gravity of water, which is 1.000. The result is the percentage of the solution which should be replaced with water.

EXAMPLE

Observed sp. gr.	1.179	Observed sp. gr.	1.179
Desired sp. gr.	1.160	Sp. gr. of water.	1.000
Difference .....	.019	Difference .....	.179
	$\frac{0.019}{0.179} = \frac{19}{179} = 10.6$		

Therefore, replace with water 10.6 per cent of the solution, or 10.6 gal. for every 100 gal. in the vat.

(b) *Beaume*.—If a Beaume hydrometer is used, the calculations are even simpler, and for practical purposes are sufficiently accurate. In this case we simply divide the difference between the observed and desired density, in degrees Beaume, by the observed degrees Beaume, to obtain the percentage of the solution to be replaced with water.¹

¹Since 22 degrees Beaume = 1.179 sp. gr., and 20 degrees Beaume = 1.160 sp. gr., the results in the above examples by the two methods of calculation should be the same, instead of 10.6 per cent and 9.1 per cent, respectively. The observed difference, which is due to the assumption that the readings of the Beaume scale are proportional to the specific gravity, is negligible in practical work, being equivalent to a difference of only 0.003 in the resultant specific gravity. Whichever instrument is used, there is no advantage in a very accurate adjustment of the density, since this will be somewhat altered by any subsequent addition of sulphuric acid.

	Example	Deg.
Observed degrees Beaume.....		22
Desired degrees Beaume.....		20
Difference		2
	$\frac{2}{22} = \frac{1}{11} = 9.1$	per cent

3—DETERMINATION OF ACIDITY

(a) *Principle*.—The amount of free sulphuric acid in the solution is determined by measuring the volume of an alkali solution of known strength which is required to neutralize the acid present in a measured volume of the solution. An indicator (methyl orange) is added to the solution in order to show, by its change in color, when all the acid is neutralized by the alkali. The method as applied to such solutions is not original, having been published by Wogrinz² in 1913. Even before that time it was used in a few electrotyping establishments in this country.³

(b) *Apparatus*.—The only essential pieces of apparatus for making this test are a pipette to measure the copper sulphate solution, a burette to measure the standard alkali, and a few bottles. Fig. 1 illustrates a form of apparatus that has been found convenient in this work. Doubtless many other forms of reservoir burettes will be found equally suitable. This apparatus and also the necessary solutions can doubtless be secured for a moderate charge from any local chemist or chemical supply house.

(c) *Solutions*.—(1) *Alkali*.—A sodium hydroxide (caustic soda) solution of any known and convenient strength may be employed. In a preliminary circular of the Bureau a solution prepared of a strength (0.61 normal) equivalent in the titration to 3.0 grams per liter of sulphuric acid was suggested. In view of the greater ease of securing a normal solution of sodium hydroxide the Bureau now recommends the use of a normal solution. One cubic centimeter (1 cc) of such a solution will neutralize 0.049 gram of sulphuric acid. If, therefore, a sample of 10 cc (or 1/100 of a liter) of the copper solution be titrated, each cubic centimeter of the sodium hydroxide required is equivalent to 4.9 grams per liter (or for most practical purposes 5 g/l or 0.67 oz./gal.) of sulphuric acid. Solutions of other strength may be employed, provided the calculations be correspondingly changed. Since the sodium hydroxide may change in strength on standing (owing to its attacking the glass of the container) it should either be renewed, or restandardized by a chemist, at intervals of about six months.

(2) *Methyl orange* solution, containing one part of methyl orange in 5000 parts of water, is used as an indicator, i.e., it changes color when all the sulphuric acid is neutralized.

(d) *Titration*.—To carry out the titration, measure with a pipette 10 cc of the copper sulphate solution to be tested (after the bath has been adjusted to the desired specific gravity and thoroughly mixed) and run it into a small flask. Add to it about 2 cc of the methyl orange solution. To adjust the sodium hydroxide solution to the zero mark in the burette, turn the center stopcock so that the burette is connected with the stock bottle, and with the bulb pump the solution until it is above the zero mark, and then shut off this stopcock. Next turn the side stopcock and allow the solution to run into any convenient vessel (for waste) until all air is displaced from the side tube and the lower edge of the curved surface of the liquid is just at the zero mark. Now run the sodium hydroxide solution into the copper sulphate solution slowly, with constant shaking, until

²Chem. Ztg., 37, p. 869; 1913.

³Private communication from Wilson Yerger.

⁴This should not be confused with a *decinormal* solution, which is often used in scientific and technical work.

the violet color of the solution just disappears. If a decided green color or appreciable precipitate appears, too much alkali has been added and a new portion should be titrated.

Note the position of the lower edge of the curve at the end of the titration. After completing the titrations, allow the burette to empty and put a little vaseline on the stopcocks.

(e) *Calculation.*—To find the number of grams per liter of sulphuric acid in the copper solution, multiply by five the number of cubic centimeters of alkali used in the above titration. To find the number of pounds of acid to be added for each 100 gal. in the bath, deduct the amount of sulphuric acid thus found from the prescribed content and multiply the result by 0.83, or practically 5 ÷ 6. (Since 1 gal. is equal to 3.79 liters, or 100 gal. equal 379 liters, we multiply by 379 the number of grams per liter required; and since there are 454 grams in 1 lb., we divide the last result by 454. For practical purposes, therefore, we multiply by 379 ÷ 454 or 0.83.)

For any given capacity of vat the correct factor can be readily determined.

Example.—Suppose 10 cc of the copper solution requires 9 cc of the alkali in the titration. Then the solution contains $9 \times 5 = 45$ grams per liter of acid. If, for example, we desire to have present in the solution 60 grams per liter of acid, it is necessary to add $60 - 45$ or 15 grams of acid for each liter of the solution. For a vat holding 100 gal. we must add 15×0.83 (or $15 \times 5 \div 6$) = 12.5 lb. of acid. Or, if the vat holds, for instance, 180 gal., we use the factor $180 : 100 \times 0.83 = 1.49$; i.e., we must add $15 \times 1.49 = 22.4$ lb. of acid.

(f) *Notes.*—(1) In the above operations and calculations extreme accuracy is not required, since all that can be accomplished is to keep the composition of the solutions approximately constant. The chief value of such tests will be to enable the operator to avoid obtaining defective work, or, in cases where the work may prove defective, to determine immediately whether the composition of the solution or some other condition is at fault.

(2) A permanent record of all titrations and of all changes in or additions to the solutions should be kept. Such records will ultimately furnish valuable information regarding the operation of the bath.

The circular is concluded by some brief non-committal notes on nickel electrotyping solutions.

The Scientific Specialties Company, of 17 Madison Avenue, New York City, has perfected arrangements with the C. P. Link Company to act as distributors for the Link water still (described in an article on page 796 of our issue of December, 1914). The Scientific Specialties Company will also act as the agents for a new hard porcelain of Bauscher make with excellent acid, alkali and heat-resisting qualities.

Coal Drier.—The Link-Belt Company has just issued a pamphlet on the Wendell drier in which the drying of washed coal for coking purposes is carried out by centrifugal force in automatic and continuous operation.

The Chapman Engineering Company, Mt. Vernon, Ohio, report considerable improvement in the gas producer trade. They have recently received an order from the Irtysh Corporation, London, England, for two 10 ft. Chapman rotary full mechanical producers. These will be installed in their zinc smelter at Ekibastous, Siberia. The New Jersey Zinc Co. have ordered four producers of this same type for their Palmerton, Pa., plant. These producers will gasify anthracite coal.

The Tapalog, a New Multiple Record Pyrometer Recorder

The Wilson-Maeulen Company, 1 East 42nd Street, New York City, has just placed on the market a new pyrometer recorder for multiple records, called the Tapalog, which embodies various radically new and decidedly interesting features.

Fig. 1 shows the tapalog operating in connection with four thermocouples.

Fig. 2 shows how in the tapalog the carriage sup-

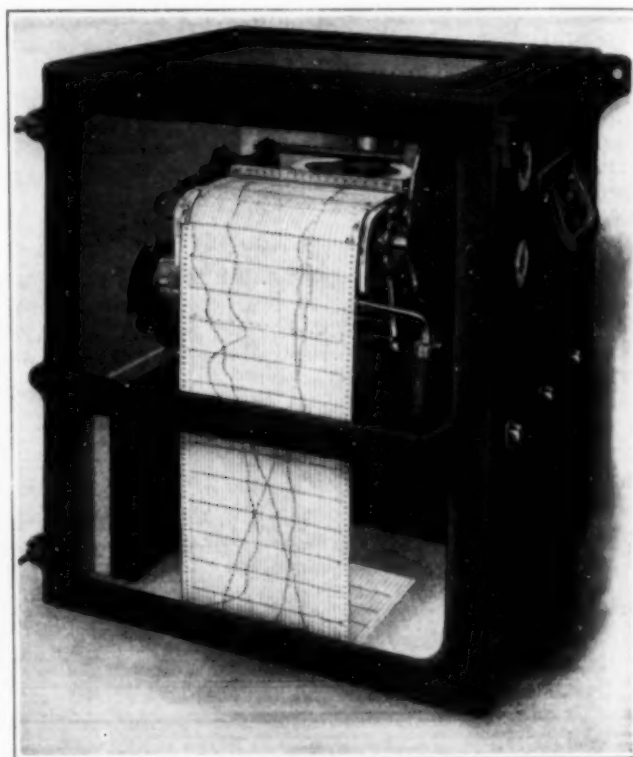


FIG. 1—THE TAPALOG OPERATING IN CONNECTION WITH FOUR THERMOCOUPLES

porting the record materials is lowered for change of paper and ink ribbon.

Fig. 3 shows the tapalog with paper roll and typewriter ribbon removed and discloses the straight edge which is the platen that results in rectangular coordinates for the record paper.

The idea of using a multi-color typewriter ribbon is new, and the idea of having the carriage, containing the ribbon and record paper, pivoted so as to swing down and away from the galvanometer is a great convenience to the operator, as the roll of paper can be taken out and the typewriter ribbon changed without having to carry on these operations in close proximity to the galvanometer.

By a crank motion the pulleys, around which the typewriter ribbon rotates, oscillate back and forth at right angles to the belt-like traverse of the ribbon so that the wear is distributed in somewhat of a sine wave. In addition to this oscillation, there is also the lateral shift, bringing the new color band into position synchronously with the rotation of the switch which connects the tapalog to another thermocouple.

In its simplest form, the tapalog has a single color band and operates with only one thermocouple, but it is generally furnished with the multi-record attachment shown at the left of photograph Fig. 2, and it will then take records of two, three or four thermo-

couples, each in a distinctive color, these colors being red, black, green, and violet.

An electromagnet, which operates the automatic switch, also operates the periodic depression of the boom carrying the indicating scale and which gives the blow that makes the dot and which boom lifts

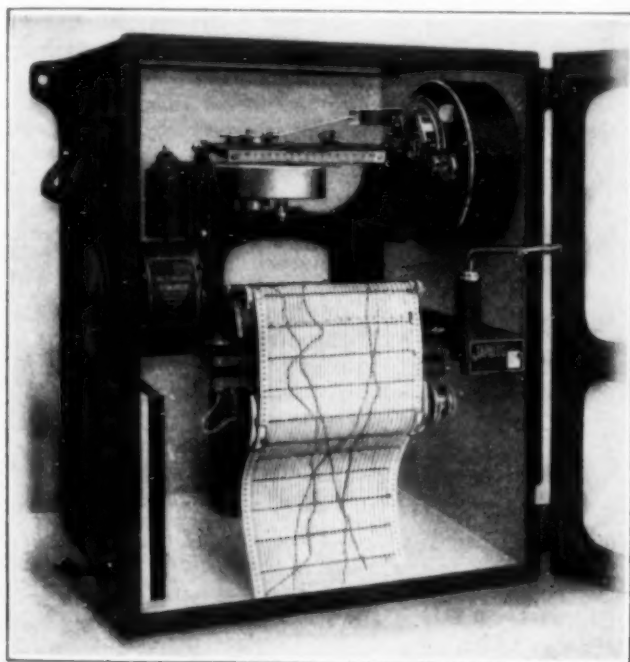


FIG. 2—THE TAPALOG WITH CARRIAGE SUPPORTING RECORD MATERIALS LOWERED FOR CHANGE OF PAPER AND INK RIBBON

slowly, leaving the pointer free to swing to its true position between the time of dotting. One dot is made every twelve seconds.

The clock has practically no work to do other than furnish the time. Actually the chopper boom is over-counterbalanced so that it tends to rise and is held

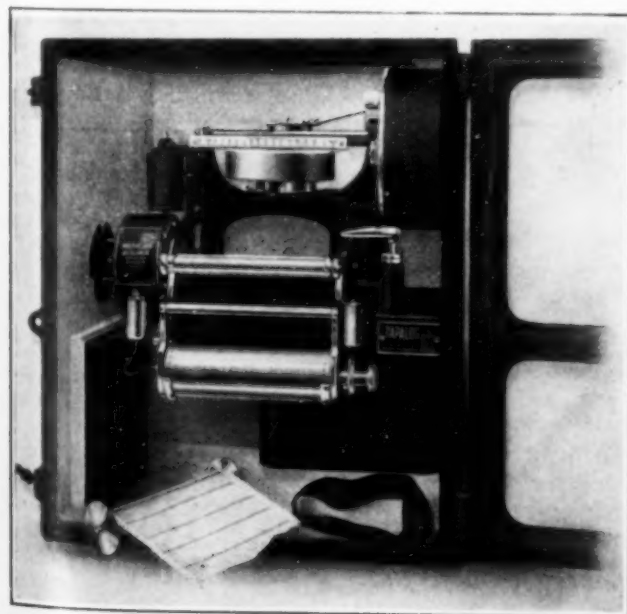


FIG. 3—THE TAPALOG WITH PAPER ROLL AND TYPEWRITER REMOVED, DISCLOSING STRAIT EDGE WHICH IS THE PLATEN THAT RESULTS IN RECTANGULAR CO-ORDINATES FOR THE RECORD PAPER

back by the clock, so that it almost drives the clock but in a way that does not disturb the good timing by the clock. This is a radically new feature in a clock-controlled recording instrument.

There is a convenient zero adjuster, accessible from the front, a start and stop lever for the clock, and a lever on the multi-record attachment enables one to instantly change the multiple recorder to a single-record type operating continuously on one thermocouple.

The instrument is in a metallic dustproof case which is even dustproof at the clock keyholes. All insulating pieces are bakelite instead of fibre or rubber.

The record paper is a good tracing paper, and the record is taken on the under side and is practically as clearly visible on one side as the other. By having the typewriter ribbon on the under side, the record is visible instantly after being made and the pointer never comes in contact with the inking material and stays clean and frictionless. The record is manifestly in shape for blue printing. The width of the record paper is 6 in. and the actual calibration is $5\frac{1}{4}$ in., and the advance of the paper is 1 in. an hour.

A two-record instrument, for instance, can be changed to a four-record instrument by the user in less than a minute by simply slipping on a four-color ribbon in place of the two-color ribbon and by making the proper connections at the binding posts on the outside of the case.

While this is a new instrument, quite a number of them are now in service, and they are taking excellent records to the entire satisfaction of the operators. Galvanometers of different sensitivity are to be used in the tapalog for different temperature ranges and different kinds of thermocouples.

The electrical contacts have been given most careful attention in the Tapalog. The contact which closes the battery circuit for operating the automatic switch and the depressing boom is platinum-rhodium on platinum, and the contact is operated by a blow from power furnished by the electromagnet itself and not by the clock; in fact, there are two of these contacts in parallel, and in addition there is provided a rotary double scraping contact, also platinum, so that it is hard to conceive of the possibility of the electric circuit not being properly closed. In the automatic switch the brush contacts are platinum-rhodium sliding over gold wires mounted on the periphery of bakelite disks.

A Flourishing German Smoke Abatement Society

BY JOHN B. C. KERSHAW

The tenth annual report of the Hamburg *Verein für Feuerungsbetrieb und Rauchbekämpfung*, which has recently made its appearance, is like all its predecessors, a valuable and instructive publication. As the Hamburg society is carrying out what is probably the most successful practical work in the cause of smoke abatement in Europe, some account of its organization and activities may prove of interest.

The society was founded in the year 1902 by a group of Hamburg manufacturers, who were convinced that some better system of control of their boiler and heating plant was desirable than the one customary up to that date. Large firms with unlimited resources and a huge coal bill could afford to employ chemical engineers to devote their whole energies and time to the scientific management of the heating and steam raising plant. The smaller power-users in the city were handicapped, however, by the difficulty of obtaining expert control or management of one or two boilers or furnaces, and

as a result of this difficulty the power plant in small factories was left too often entirely in the charge of a fireman or engineer whose scientific knowledge and technical training was quite inadequate to the demands made upon it. Smoke, inefficiency and waste were the natural accompaniments of this state of things, and it was to remedy these that the Hamburg Verein für Feuerungsbetrieb und Rauchbekämpfung was founded.

How successful the society has been in its own particular sphere of operations is shown by Fig. 1, which records in diagrammatic form the growth of the society in the various classes of membership and in the number of boilers placed under its charge since its birth, twelve years ago. The apparent set-back met with in 1911 was due to the foundation of a branch society in Helsingfors, Finland, and to the transfer to the register of the new society of some of the members and boilers of the parent organization. It is satisfactory to note that the curves both for membership and for boilers have once again assumed an upward trend, and that on April 1, 1914, the Hamburg society had 500 members and 1744 boilers and other heating installations on its register.

The work of the society is controlled by a committee of seven members, elected annually. The technical and

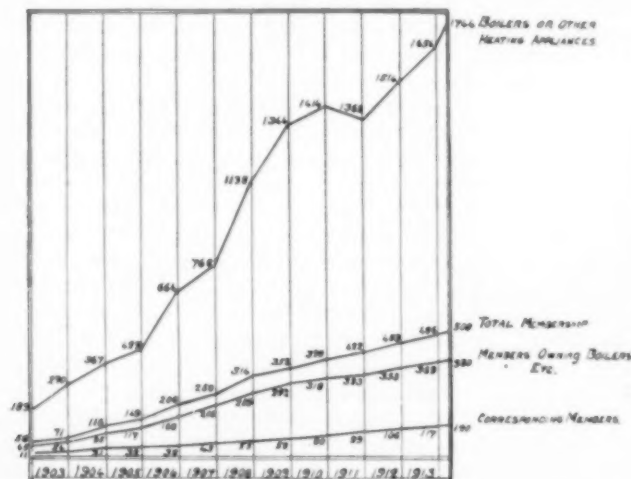


FIG. 1—GROWTH OF THE HAMBURG SOCIETY IN THE PERIOD 1902-1914

scientific work is undertaken by the staff of experts retained by the society for this special purpose. At the date of the last report this staff consisted of a chief engineer, three assistant engineers, five instructors for firemen and three clerks—while for special steam-raising and other trials additional assistance had been employed. The chief engineer attends the committee meetings and takes part in the discussions relating to the work of the society. The funds of the society are drawn from three sources: From the annual subscriptions of its members; from payment for special work and reports for its members; from payments for outside work.

The society is thus entirely self-supporting and its success is dependent upon the value of the return it makes to its members for their contributions and fees.

The objects of the society, as set forth in the rules, are the attainment of the highest possible efficiency from the heating and boiler plants of its members with the least possible emission of smoke. To this end regular examination of these plants and of the methods of working them is undertaken by the expert staff of the society, and suggestions are made for improvements when such are required. The education and control of the firemen in the proper performance of their duties are also undertaken by the firemen-instructors on the

staff of the society. Comparative tests of fuel and tests of smoke prevention devices and other appliances of a similar character are also carried out by the expert staff and the results are circulated among the members of the society.

Each boiler or heating plant, when brought under the control of the expert staff of the society, is tested at the earliest possible date, and a written report upon the results of the examination is submitted to the owner. Should the firing have proved inefficient one of the firemen instructors is sent to the works to give practical instruction to the firemen employed there, and tests of

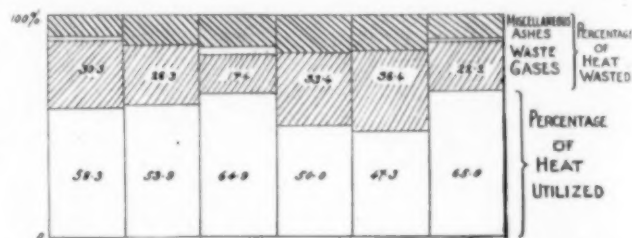


FIG. 2—RESULTS OF THE FIRST TRIALS BEFORE SPECIAL TRAINING OF STOKER

the plant are made at intervals until this fault is remedied. Defects in design are similarly dealt with.

The annual subscription to the society for members without any boiler or heating plant (fördernde mitglied) is 20 marks (\$5). Members having boilers or furnaces which they desire to place under the control of the experts of the society pay a further 20 marks (\$5) annually for each boiler or furnace.

The extra charges for tests and reports are based upon the time spent upon them and the number of experts employed. Engineers are charged for at the rate of 20 marks (\$5) per day and firemen-instructors at 5 marks (\$1.25) per day. Special reports upon patented appliances are charged for at the customary rates; members receive a special discount of 30 per cent on these as compared with outsiders.

Turning now to a consideration of the practical results of the work carried on by the society, as recorded in the past annual reports, we find that great stress is laid upon the improvements in efficiency due to the training of the stokers in the proper performance of their duties and figures are given in every report showing



FIG. 3—RESULTS OF THE FIRST TRIALS AFTER SPECIAL TRAINING OF STOKER

gains in efficiency varying from 10 per cent to 20 per cent from this one cause alone. As examples of the gains which have followed from the society's control of boiler plants the two diagrams, Figs. 2 and 3 (taken from the 1912 report), are interesting, since they show in graphic form the results of tests on the same boilers before and after the engineers of the society had taken charge of the respective plants.

The heat loss in chimney gases, ashes, etc., is here seen to have varied between 35 per cent and 53 per cent when the boilers were working under the normal conditions, i.e., in charge of their usual stokers; while after

the society's expert staff had taken control the total heat losses were reduced to between 21 per cent and 32 per cent. The best efficiency recorded in these diagrams is that of No. 2 installation, with 79.6 per cent of the heat value of the fuel utilized in steam-raising, compared with only 59.9 per cent utilized before the transfer of the boiler plant to the company's charge. This represents a gain of 19.7 per cent in efficiency and a saving of 20 per cent on the coal bill.

It is most important to note that the society does not merely test each boiler or furnace plant once and then leave the stokers or engineers to their own devices again. The plant is visited, inspected and tested at regular intervals of time and by systematic instruction and oversight of the regular firemen at their work, an attempt is made to render permanent the gains shown by the first run under more scientific conditions. The staff of "instructors for firemen" have an important rôle to fill in this regular work of the society, for when any plant is not producing the results expected from it one or more of these expert firemen is sent and instruction and advice are given on the spot to the regular fireman of the plant. When necessary the expert fireman takes sole charge of the boilers and fires for an hour or two while the regular fireman looks on. This undoubtedly is the best way to train firemen in the practical side of their duties, for though evening classes and lectures have their value and place they can never be a satisfactory substitute for practical oral instruction given on the firing-plate of the boilers by a man who can handle a shovel as well as he can explain the chemistry of combustion.

Enough has been said above to indicate the general lines and methods of the Hamburg society's work and the results achieved and a small space may be devoted now to the special investigations referred to in the last report. For the expert staff of the society in addition to its regular control of the steam-raising and heating plant of its members is always carrying on special tests of new forms of grate or of some other accessory of boiler plant. Latterly a very large number of comparative tests have been made with mechanical stokers of both the "sprinkler" and "coker" types. The results of these special tests are included in the annual reports, and a complete set of past reports of the Hamburg society is therefore a most valuable addition to the reference library of all consulting engineers who are specially interested in boilers and steam-raising plant.

The special investigations that are dealt with in the tenth report are the following:

1. Trials and tests with mechanical stokers: (a) Sprinkler type; Axer; Dingler, "Man," Weck, Mückner, Seyboth. (b) Chain-grate stokers. Babcock & Wilcox, "Bamag," "Man," Steinmüller.
2. Trials and tests with regulators of secondary air supply to hand-fired boilers.
3. Tests of water-cooled hollow bar. German "Prometheus" grate.
4. Ships boilers and their methods of firing; cylindrical boilers.
5. Artificial draft for boilers.
6. Domestic heating appliances.
7. Results of fuel-tests.

With reference to the last subject in this list it may be stated that for the past three years the Hamburg society has taken considerable interest in the movement for purchasing fuel on a more scientific basis and that it has appointed Dr. Aufhauser, of the Thermo-Chemische Prüfungs-und Versuchs-Anstalt, in Hamburg, official fuel analyst for the society. A large number of members of the society take advantage of this arrangement to have regular samples taken and tested

of their fuel supplies, and the last report of the Verein contains many hundreds of test results of the fuel samples taken in 1913 and in preceding years. As the fuels are classified under the county or district from which they come and more than one-half the tests refer to English and Scotch shipping coals, this appendix to the report is of more than local interest and value.

Further Notes on the Refractory Properties of Zirconia

BY H. CONRAD MEYER

The remarkable heat-resisting properties of zirconia have been known for many years, but it is only within the last few months that serious attention has been given in America to its possibilities in metallurgy and furnace technology. The reader is referred to an article appearing in this journal for a brief history and description of zirconia.¹ Heretofore, zirconia has been considered one of the rare oxides and hence of limited application. It is now being supplied, however, in commercial quantities, and in many instances, is now being used on an industrial scale. A free exchange of ideas among many investigators has rapidly advanced the technology of zirconia, and the writer hopes that the preliminary data here given may be of value to all those now working on this new refractory body. Many of the investigations have been carried out by the author, and numerous independent reports have been secured from private sources, for which due credit is given.

Analysis of Natural Zirconia

In the investigation of refractory substances, a complete chemical analysis is often found of value. The presence of alkalies, silica and iron oxide often plays an important part in the behavior of the material when subjected to high temperatures. The mean of three analyses of an average sample of natural zirconia is given herewith:

ZrO ₂	84.1
SiO ₂	7.74
Fe ₂ O ₃	3.10
TiO ₂	1.21
Al ₂ O ₃ .....	.66
Loss on ignition.....	2.72
	<hr/>
	99.53

It will be noted from the above, that the only two oxides present which would be likely to cause a lowering of the melting point of the zirconium oxide, are silica and ferric oxide. The 1.21 per cent of titanium oxide present, may or may not exert a fluxing action at high temperatures, but the practice seems to be, in manufacturing most fire brick and refractory ware, to disregard this oxide entirely. The ignition loss consists mainly of moisture with a small percentage of organic matter.

Heat Tests on Zirconia²

An ore containing 84 per cent ZrO₂, ground to 100 mesh and mixed with H₂O, molded easily into cones which kept their shape when burnt with little warpage or shrinkage to about the temperature of cone 35 (1830° C.). These tests on cooling show a slightly vitrified material with a smooth and fine-grained surface.

Zirconia mixed with a 5 and 15 per cent mixture of Bens Creek clay, in view of finding a suitable bonding material, and heated to a temperature over cone 31 (1750° C.), shows the 15 per cent tests to be in fair

¹Met. & Chem. Eng., Vol. 12, No. 12, page 791, Dec., 1914.

²Data taken from the results of three or more tests on separate mixtures by G. T. Stowe.

shape, that is, slightly vitrified, cracked and coarser grained, while the 5 per cent test is in good shape with a fine finish and very little shrinkage or warpage. A mixture of 5 and 15 per cent Warrior Ridge clay with the zirconia and heated to the temperature of about cone 32 (1770° C.) shows the 5 per cent mixture to be in excellent shape with a clean cone standing at the end of the test. The 15 per cent mixture does not hold up quite as well at the same heat.

A mixture consisting of 98 per cent 100-mesh zirconia and 2 per cent slacked lime worked into a plastic form with H₂O, showed a fusion point of about cone 30 (1730° C.). Further, this cone lost its shape by warping at least five cones before the mixtures with clay.

The mixtures on a whole were easily molded. The pure zirconia test cones seemed to have some plastic properties and held together very well, making a clean and sharp-edged cone.

The burnt product seems to be a likely refractory material, granting that the higher heat and flux standing properties make up for the advance in the cost of manufacturing the material in comparison with other refractory wares. The vitrified samples show a very hard and seemingly strong ware.

Of all the tests made, the 5 per cent mixture of Warrior Ridge clay with the zirconia seems to make the best bond; produces the best appearing samples before and after burning, the pure zirconia tests excepted, and those only as to heat tests.

Fire Shrinkage^a

Small briquets of the following were carefully made, measuring 36 x 20 x 5 mm. These when thoroughly dried, were burnt at a temperature of approximately 1427° C. in a No. 2 muffle furnace supplied by the American Gas Furnace Company.

- No. 1. Pure zirconium oxide (99 per cent ZrO₂).
- No. 2. Wet ground zirconia (84 per cent ZrO₂).
- No. 3. Zirconia (95 per cent ZrO₂).
- No. 4. 93 grams of No. 3, and 7 grams Dry Branch kaolin.
- No. 5. 60 grams zirconia, 80 mesh (84 per cent ZrO₂) and 40 grams wet ground zirconia.

Linear shrinkage at 2600 deg. F.:

No. 1.....	9 per cent.
No. 2.....	9 per cent.
No. 3.....	9 per cent.
No. 4.....	12 per cent.
No. 5.....	3 per cent.

Briquet No. 1, made from pure zirconium oxide, analyzing about 99 per cent ZrO₂, yielded a sticky mass on mixing with water and was quite soft after drying. After burning No. 1 was still in a soft condition and could be readily scratched with the nail.

Briquet No. 2 consisted of natural zirconia carrying about 84 per cent ZrO₂, corresponding to the analysis given above. As indicated, this material was wet ground in a ball mill and thus reduced to an extremely fine state of subdivision. It was readily molded into shape. Firing rendered the material extremely dense and of a flint-like hardness. Several briquets were heated to redness and one end plunged into a beaker of water. This quenching test apparently left the material unaffected, as no cracks were developed.

Briquet No. 3 was made from 95 per cent zirconium oxide. This 95 per cent product was prepared on a small scale from the natural or 84 per cent zirconia. Most of the silica and nearly all of the iron were removed by this refining, which yielded a light gray product. After firing, the briquets presented a very dense structure and were extremely hard.

^aAuthor's tests.

Briquet No. 4 shows the bad effect of even a small percentage of a very refractory china clay. Dry Branch kaolin is a pure white, washed clay, having a fusing point above 1790 deg. C.

Briquet No. 5 was made from a mixture of 60 grams coarse zirconia (material passing through an 80 mesh screen) and 40 grams water-ground zirconia, or material similar to No. 2. It will be noted that the shrinkage in this case was extremely low. The briquet, after firing, presented a rather coarse, porous texture, but possessed considerable tensile strength.

Whether these shrinkage figures would be greater at higher temperatures, it is difficult to say.

Selection of a Binder

The proper choice of a binder is a very important consideration, as the fusing point of the zirconia is influenced largely by the substance added as a bond. Phosphoric acid, sodium silicate, and lime were tried, but with indifferent success, and in many cases it was clearly apparent that such bonds were positively detrimental.

The following data were secured from a private source.^b The tests were made in the form of small briquets measuring 1 1/4 x 1 1/4 x 4 in. in a steel mold. The material was rammed in place with considerable pressure. Five such tests were made as follows:

(1) Zirconia powder, bonded by 26.5 deg. Bé MgCl₂ solution (concentrated from salt bittern). Mixed to consistency of a stiff mud and rammed. Dried 5 days—100 deg. C. Dried 8 hours—150 deg. C. Heated gradually to bright red and exposed to temperature of 1600 deg. C in an electric arc furnace for two hours. The sample showed no fusion; corners sharp and hard; scratch glass; shrinkage slight; FeO and Fe adhere in molten condition; FeO showed corrosion; very dense; difficult to crack with bricklayer's hammer.

(2) Zirconia powder, 50 per cent; dead-burnt magnesia (electrically dead-burnt), 50 per cent; bonded by 26.5 deg. Bé MgCl₂ solution and mixed to hard, stiff mud and rammed. Dried same as 1. Heated to same temperature and for same time as 1. Fused to spongy mass, dark color. The fusion was evidently caused by iron oxide and silica.

(3) Zirconia powder, 10 per cent; dead-burnt magnesia, 88 per cent; 26.5 deg. Bé MgCl₂ solution, 2 per cent. Mixed to stiff mud and rammed. Dried and heated same as for 1. Hard, dense, compact brick; sharp, hard corners; positively no fusion; showed no corrosion by FeO; light brown color.

(4) Zirconia powder; bonded by 30 deg. Bé Na₂SiO₃ solution to form stiff mud and rammed. Dried and heated same as 1. No fusion; extremely hard, dense; interior appeared denser than exterior; slight crack in interior, probably due to moisture.

(5) Zirconia powder; bonded by small amount of water in form of vapor, mixed to stiff mud and rammed. Dried and heated same as for 1. Compares to properties of 1. Showed same FeO corrosion.

With the exception of 2, which fused, the samples showed:

- (1) General corrosion by FeO in spots.
- (2) Slight shrinkage.
- (3) Withstood temperature changes from 500 deg. C. to 1600 deg. C., without any cracking or spalling.
- (4) No contortion or deformation at high temperature.
- (5) Precaution necessary in choosing suitable binder, and also care to be used in mixing with other refractory substances containing impurities as FeO, SiO₂, etc.

^bR. C. Gosrow.

(6) Zirconia can be used equally with magnesia, and with less cost for linings, etc.

The results secured by Mr. Gosrow under test No. 3 appeared promising enough to warrant further investigation along this line. Preliminary tests indicate that magnesium chloride would be objectionable on a commercial scale. Hence, another binder was sought and ultimately found in water-ground zirconia. It was further considered that the dead-burnt magnesia (electrically dead-burnt) might be successfully replaced by ordinary calcined magnesite, such as is used for magnesite cement in flooring. This product carries about 93 per cent magnesium oxide, with a small percentage of carbon dioxide, calcium oxide and silica.

The following formulas were used² in the making of several small briquets which were carefully dried and burnt at a temperature of approximately 1427 deg. C. in a small muffle furnace:

FORMULA 3A

45 grams zirconia (ground to pass through 80 mesh screen).

45 grams magnesium oxide (calcined).

10 grams water-ground zirconia.

The briquets after burning were of a brownish yellow cast, with a rather loose texture, but quite resistant to abrasion and of a fair tensile strength. The fire shrinkage at the above temperature was approximately 8 per cent linear measurement. One of the briquets at a white heat was dropped in a beaker of water, but no cracks were developed and the material was apparently as solid as before quenching.

FORMULA 3B

72 grams zirconia (ground to pass through 80 mesh screen.)

18 grams magnesium oxide (calcined).

10 grams water-ground zirconia.

Briquets made from this formula had very much the appearance of those produced by formula 3A. The fire shrinkage was approximately the same. The specific gravity was, of course, higher, owing to the greater percentage of zirconia present. The results of these tests were considered rather encouraging, and further investigations are now under way. The strong objection to the use of the magnesium oxide, particularly the calcined product, is the fact that it has an extremely high shrinkage. This of course is not true of the costly electrically shrunk magnesite oxide, but the tendency would naturally be toward the use of the cheaper calcined oxide.

Fire Clay Bond

As will be noted under fire shrinkage, briquet No. 4, mixed with a 10 per cent bond of refractory clay, showed extremely high shrinkage. It was decided, however, to manufacture a few standard-size fire bricks, using a 5 per cent bond of Warrior Ridge clay, as mentioned above. The zirconia was ground to pass through an 80-mesh screen, and thoroughly mixed in a dry pan with 5 per cent of the aforementioned clay. The mass was slightly moistened and formed into bricks in the same manner as is pursued in the manufacture of silica or chrome bricks. After thoroughly drying, these bricks were burnt in a silica brick kiln, at an estimated temperature of at least 1649 deg. C.

No figures were secured as to the fire shrinkage, but even this small percentage of clay caused the bricks to soften at a temperature well below the fusion point of the natural zirconia. The standard bricks made from the material weighed on an average 11¼ lbs. each.

To determine the behavior of the material when in

contact with carbon at high temperatures,³ a brick was made a part of one side of the trough of a granular carbon resistance furnace, the rest of the trough being made of magnesite brick, all being backed up by fire brick. A pyrometer tube was put in so as to give the temperature of the surface of the brick, next the carbon resistor, and temperatures read with a Wanner pyrometer. In about one half hour after starting, the temperature was 1800 deg. C. \pm 25 deg., and it was held between 1750 deg. and 1850 deg. C., averaging 1800 deg. C. \pm 25 deg. for 1½ hours. The furnace was then torn apart. The zirconia brick was just nicely red on the back (2½ in. from the resistor), while the magnesite bricks were much redder. From this and from the temperature of the fire brick backing when felt from time to time, it is plain that zirconia has a considerably lower thermal conductivity than magnesite, and quite probably the lowest of any available material that will stand 1800 deg. C.

The brick when put in place, had a slight crack, and this increased a little on heating, but not very badly. Magnesite bricks on both sides of it were badly cracked. A slight shrinkage was noted on the hot face, and the surface of the zirconia brick was slightly pitted and spongy. The spongy layer was only about ¼ in. thick. The magnesite bricks were considerably more acted upon by the carbon than the zirconia bricks, their surfaces being eaten away uniformly over ¼ in. Hence, as regards the action of carbon on the hot brick, the zirconia brick appears superior to magnesite, but inferior to carborundum.

The zirconia brick was not supporting any weight, and only the inner face reached 1800 deg. C. The brick had not really fused nor flowed of its own weight, *i. e.*, it might not have failed under a "cone test" at 1800 deg. C. Yet when the brick was picked up with tongs, they sank into the hot face, under gentle pressure, to a depth of ½ in.

The face of the brick was very plastic, and though it had not really fused nor flowed out of shape, the fact that the brick as a whole kept its shape was due to the stiffening effect of the comparatively cold back of the brick. If the whole brick had reached 1800 deg. C. and had been under any pressure, as in a wall with other courses of bricks resting on it, it would certainly have been pressed out of shape.

It therefore appears that 1800 deg. C. is the upper limit at which this brick (zirconia bonded with Warrior Ridge clay) could be safely used. It is, of course, quite possible that a brick bonded with water-ground zirconia and free from clay bond, might be stiffer and stand up at a higher temperature.

Therefore, while this particular brick is not as refractory under furnace conditions as the reported melting point of zirconia would lead one to expect, it is still refractory enough to be classed among the half dozen highest refractories; while not entirely free from shrinking and cracking, its behavior in this respect is far better than magnesite, although not as good as carborundum. Its heat conductivity is apparently less than any other of our high refractories. Its behavior in contact with carbon, while not perfect, is not so bad but that it can probably be controlled.

Zirconia Crucibles and Similar Shapes

In the manufacture of crucibles, muffles, etc., from zirconia, it should always be borne in mind that the material has an extremely low thermal conductivity. Hence, the walls of the crucible or other shape must be considerably thinner than would be the case if clay were used. Owing to the high tensile strength of zirconia

²By J. R. Adams under author's supervision.

³The following data was contributed by an experienced investigator, who requests that his name be withheld.

when properly bonded and burnt at a sufficiently high temperature, it is possible to make such objects without the danger of breakage through handling. Another important consideration in the use of zirconia in crucibles is its resistance to fluxes and slags. It has been suggested that water-ground zirconia might prove very efficient as a lining for graphite crucibles. Shallow dishes, trays and small crucibles have been made experimentally by hydraulically pressing various mixtures of coarse zirconia bonded with water-ground material, producing ware of high tensile strength and of extreme thinness. Shallow dishes have been pressed in this way, having a diameter of 6 in. and maximum thickness of not over $\frac{3}{8}$ in.

Although this article does not concern itself with the uses and applications of chemically pure oxide of zirconium, it is interesting to note that two patents have recently been granted for the manufacture of utensils and the like from the oxides of the rare earths, such as thorium, zirconium, etc.

While the foregoing results should not be accepted as final or conclusive, they apparently presage important industrial uses for this new refractory.

Laboratory, Foote Mineral Co.,
Philadelphia, Pa.

The Dedication of the New Building of the Mellon Institute

BY W. A. HAMOR*

The new \$350,000 building which will form the permanent home of the Mellon Institute of Industrial Research and School of Specific Industries of the University of Pittsburgh, was formally dedicated on Feb. 26. This building, the gift of Messrs. Andrew William and Richard Beatty Mellon, of Pittsburgh, was especially designed for the needs of the institute; it is distinctly



THE NEW BUILDING OF THE MELLON INSTITUTE IN
PITTSBURGH

modern in every respect and complete facilities are provided for the investigation of manufacturing problems and for conducting industrial research according to the practical system of co-operation between science and industry, founded by the late director of the institute, Robert Kennedy Duncan. By this system an industrialist having a problem requiring solution may become the donor of a fellowship by providing the salary of the researcher selected to carry out the investigation desired, the institute supplying every facility for the work—laboratory space, the necessary apparatus and supplies, library facilities and advice of a staff expert in industrial research, etc.

The new home of the Mellon Institute is a five-story

and attic building. The basement contains seven rooms: the main storeroom, the boiler room, the electric-furnace room, a heavy-apparatus room, a room equipped for low-temperature work, the machine shop and the kitchen. On the first, the main floor, are located the general office, the director's suite, the office of the editorial department, the library, the office and laboratory of the assistant directors, the assembly hall, a special apparatus room and a dark-room laboratory. The second and third floors each contain ten large research laboratories and nine small ones; the fourth floor, which is not finished, will contain an identical number of laboratories as soon as the growth of the institute warrants its completion. At the present time twenty-three fellowships are in operation and forty research chemists are engaged in a study of the variety of industrial problems under investigation at the institute.

While the Mellon Institute possesses an endowment of its own and has its own board of trustees, it is an integral part of the University of Pittsburgh. The dedicatory ceremonies were accordingly held in conjunction with the annual Charter Day exercises of the University.

The chancellor of the university, Dr. Samuel Black McCormick, presided at the dedication ceremonies, which took place at 11 a. m. in Soldiers' Memorial Hall, in conjunction with the annual Charter Day exercises of the University. Following the address of the day by Dr. Rossiter Worthington Raymond on "Knowledge and Research," Dr. W. J. Holland, director of Carnegie Museum and formerly chancellor of the university, made the presentation speech in connection with the dedication of the Mellon Institute, on behalf of Andrew W. and Richard B. Mellon, the donors. After a tribute to the generosity of the Messrs. Mellon, Dr. Holland said in part:

"In a certain sense this building is a memorial to Robert Kennedy Duncan. On one side of the entrance is a bronze slab inscribed with the name of Thomas Mellon; on the other side of the entrance is a bronze slab inscribed with the name of Robert Kennedy Duncan. But this splendid edifice erected upon the campus of our University is more than a cenotaph. It not merely commemorates the names and careers of those of whom I have spoken, but it is intended to serve as the seat of advanced inquiries along scientific lines, which will tend to the promotion not merely of intellectual culture, but of industrial success, and that not merely in this great 'workshop of the world,' where it is located, but throughout the land. In creating this institution our dear friends have been actuated by a high and intelligent purpose. Large experience in great industrial enterprise has taught them the importance of chemistry and physics in their application to the industrial arts, and they feel, that, wonderful as has been the progress made within the last century, there are untold mysteries in nature, which have not yet been revealed, but which, if uncovered, are capable of being used for the welfare of mankind. And so they have created and are today placing in the custody of you, gentlemen of the Board of Trustees, this institution, which is capable of becoming, when wisely and intelligently administered, a mighty implement for the advancement of human welfare."

Dr. George Hubbard Clapp, president of the board of trustees of the University, delivered the speech of acceptance. He expressed appreciation of the gift and understanding of the importance of the work for which the building has been erected.

The final ceremony of the exercises was the conferring of fifteen honorary degrees. The degree of Doctor of Laws was conferred on Edward Williams Morley, John Ulric Nef, Arthur Amos Noyes, Rossiter Worthington Raymond, Ira Remsen and Theodore William Richards.

The degree of Doctor of Science was conferred on John Jacob Abel, George Hubbard Clapp, Elbert Henry Gary, John Hays Hammond and Henry Marion Howe.

The degree of Doctor of Chemical Engineering was conferred on William Hultz Walker, Milton C. Whitaker

*Published by permission of Dr. Raymond F. Bacon, Director of the Mellon Institute.

and the degree of Doctor of Chemistry on Charles Lathrop Parsons and Edgar Fahs Smith.

Immediately after the close of the dedicatory exercises, the trustees, faculty and guests of the University met at a luncheon in the University Club. The remainder of the afternoon was devoted to an inspection of the new building of the Mellon Institute.

The recipients of honorary degrees were the guests of the University at the annual alumni banquet held at the Schenley Hotel from 6 to 8:30 p. m. The speakers at this dinner were Dr. Raymond F. Bacon, director of the Mellon Institute, who responded to "The Mellon Institute"; Dr. Walther Biddle, who gave an historical sketch of the department of chemistry of the University; Hon. Elbert H. Gary, chairman of the United States Steel Corporation; Dr. Theodore William Richards, who spoke on "The Practical Use of Research in Pure Science" and extended Harvard's congratulations to Pittsburgh upon the acquisition of the Mellon Institute; and Chancellor Samuel Black McCormick, who completed the toast list with an eloquent response to "The University," in which he stated that the gift of the Mellon Institute had placed a great responsibility upon the University of Pittsburgh as well as having been a priceless acquisition; that the University was ready to meet the responsibility and, he felt sure, would show the donors and the country at large that it would make the most of the great benefaction.

After the banquet the new building of the Mellon Institute was thrown open for a reception of friends of the institute. The rooms of the main floor were used for the reception, although the entire building was open for inspection. On the evening of Feb. 27, the first Mellon lecture was delivered by Prof. John Jacob Abel, of Johns Hopkins University, in the assembly hall of the institute; Dr. Abel's subject was "Experimental and Chemical Studies of the Blood and Their Bearing on Medicine."

Personal

Mr. T. A. Bennett, who for the past five years has had charge of the conveyor and elevator belt sales of the B. F. Goodrich Company, Akron, Ohio, is severing his connection with the Goodrich Company on March 1st, to become the assistant to the general sales manager of the New Jersey Zinc Company, with offices in New York City. Mr. Bennett will be succeeded by Mr. J. D. Mooney, formerly special mining representative for the Goodrich Company.

Mr. O. M. Bilharz has resigned his position as technical manager for the St. Joe and Doe Run lead companies in southeastern Missouri.

Dr. John C. Branner, president of the Leland Stanford, Jr., University, Cal., has resigned to take effect July 31, 1915.

C. F. Burgess Laboratories is the new name of the Northern Chemical Engineering Laboratories of Madison, Wis. There is no change in management or ownership, and the concern of which C. F. Burgess, formerly professor of the University of Wisconsin, is president, will continue as heretofore its practice in chemical engineering, research, and industrial development.

Mr. Arthur Crowfoot has been appointed superintendent of the concentrator of the Arizona Copper Co., Morenci, Ariz. He was formerly engaged in various capacities at the Boston & Montana reduction works of the Anaconda Copper Mining Co.

Dr. Carl Hering, of Philadelphia, Pa., has been elected a Fellow of the Association for the Advancement of Science.

Mr. V. D. Howbert was recently elected president of the Colorado School of Mines Scientific Society, a student organization. C. E. Carstens is vice-president and F. E. Briber secretary.

Dr. W. C. Huntington has been appointed commercial agent in charge of the Chicago branch of the Bureau of Foreign and Domestic Commerce. He succeeds Mr. H. H. Garver, who has accepted the position of foreign trade commissioner of the Chicago Association of America.

Mr. W. J. Kee, Jr., for the past four years superintendent of the Argentine acid plant of the National Zinc Company (formerly the United Zinc & Chemical Company), has resigned to become connected with the new acid plant designed by Mr. Utley Wedge for the Anaconda Copper Company, Anaconda, Mont.

Mr. Edward W. Lawler, for many years with the Hardinge Conical Mill Co., the Abbe Engineering Co., and other concerns, is now connected as sales engineer with the Jeffries Mfg. Co., with headquarters at 77 Warren Street, New York City.

Mr. John L. Malm has returned to Denver from a professional trip to Chicago.

Ricketts & Banks, New York, have dissolved their copartnership by mutual consent, and each will continue separately in business as mining, metallurgical and chemical engineers. Ricketts & Co. will be located at 80 Maiden Lane, and Dr. John H. Banks at 61 Broadway.

Mr. L. T. Ticka has resigned his position as mechanical superintendent of the International Smelting Company, Tooele, Utah, to become the mechanical superintendent and engineer for the St. Joseph Lead Company, Bonne Terre, Mo.

Mr. H. E. Tuttle has severed his connection with the Edgar Zinc Company and is with the Fink Furnace Company, Chicago.

Obituary

Frank L. Clerc died in Denver, Colo., March 9, 1915. Mr. Clerc had long been identified with the zinc industry and was well and favorably known as a metallurgist in that branch of ore treatment. Although he had not been engaged in active practice in recent years, his interest in his chosen line of work did not abate, and he continued his studies and researches practically up to the time of his death. As a contributor to technical literature he was known to a wide circle of metallurgists. Shortly before he returned to Denver from an eastern trip during the winter, he was engaged in gathering together his contributions which had appeared in this journal and elsewhere, with the idea of republishing them in book form. In recent years he had been much interested in the metallurgical problems confronting the producers of low-grade carbonate and silicate zinc ores at Leadville. On this subject he proposed a number of methods of procedure, bearing particularly on igneous concentration. He also invented a form of furnace that he considered specially applicable to the reduction of the zinc oxide that would result from fire concentration of low-grade ores.

Mr. Clerc was born in Pennsylvania on February 22, 1851. He studied and graduated at Lehigh University and came west, finding a field for his activities in the zinc district of Missouri and later in New Jersey. At different times he was identified with the faculties of the Massachusetts Institute of Technology and the Colorado School of Mines. He is survived by two sisters, one of whom lives in Phillipsburg, Pa., and the other in Wilton, Conn.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903.

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath, Electroplating Alloys

273,324, March 6, 1883, Joseph M. Thomas, of Auburn, N. Y., assignor to Byron C. Smith, of same place.

Relates to electrodepositing brass upon steel, malleable, cast or wrought iron, or upon tin, lead, bismuth, type or britannia metal, from a solution prepared as follows: 1 ounce (avoirdupois) of crystallized acetate of copper is dissolved in 8 ounces (liquid measure) of ammonia water of 26 deg. B.; in 1 gal. of distilled or rain water, at 165 deg. Fahr., is now dissolved 18 ounces (avoirdupois) potassium cyanide; to this cyanide solution is now added 2 ounces crystallized acetate of zinc, with stirring until dissolved; the acetate of copper and ammonia solution is now added and lastly $\frac{1}{4}$ ounce (liquid measure) commercial hydrocyanic acid. The solution thus prepared is heated to about 165 deg. Fahr. and used as the electrolyte with either copper and zinc or brass as anode. The color of the brass deposit is determined by the current strength; a strong smooth current is recommended.

477,350, June 21, 1892, Edward T. Burrowes, of Portland, Maine.

Relates to electroplating wire-screen-cloth made of brass, copper or composition or other bright smoothly finished wire, so as to diminish its excessive brightness, toning it down to a darker and more subdued color, rendering it less conspicuous and better adapted for house-screen use. The electrolyte is made by dissolving 30 lb. of copper sulphate, $1\frac{1}{2}$ ounce caustic potash, 10 lb. zinc sulphate, 6 ounces tin chloride, 5 lb. sal-ammoniac and 8 ounces muriate of iron. This is deposited electrically by means of an anode composed of 8 lb. of copper and $1\frac{1}{2}$ lb. each of tin and zinc. The plating process changes the bright-wire screening to a fine dark-brown color resembling statuary bronze, which is said to be permanent and not liable to be affected by the atmosphere.

487,176, Nov. 29, 1892, Sherard Osborn Cowper-Coles, of London, England, assignor of one-half to the London Metallurgical Company, Ltd., of same place.

Relates to electrodepositing upon metals or other suitable objects an alloy better adapted than silver to resist the tarnishing influences of the atmosphere. The alloy consists of zinc and silver, or cadmium and silver, or zinc, cadmium and silver; the proportions varying from 35 per cent to 25 per cent, or less, of the zinc or cadmium; or a cheaper alloy may be made with from 40 per cent to 90 per cent of the base metal. The electrolyte is prepared as follows: A suitable quantity of cyanide of zinc or cadmium is dissolved in a solution of cyanide of potassium, so as to form a double salt having an excess of cyanide of potassium. To this solution is added a small quantity of the double salt of the cyanides of potassium and silver. The electrolyte thus prepared may be used hot or cold. An anode of approximately the composition of the alloy deposit desired is employed, the hardness of the alloy varying with its composition. (See also his later patent, No. 512,160.)

512,160, Jan. 2, 1894, Sherard Osborn Cowper-Coles, of London, England, assignor to the London Metallurgical Company, Ltd., of same place.

Relates to the alloy deposit produced by the process described in his patent, No. 487,176, which should also be consulted. The alloy consists of silver and cadmium, silver and zinc, or silver, cadmium and zinc or any other known metal or metals, other than indium, having

a specific gravity between 6.5 and 9, and boiling at a temperature between 710 deg. C. and 1045 deg. C., these alloys being employed with or without the addition of any or all of nickel, cobalt, tin and chromium. The anodes employed in the electrodeposition may be carbon, lead or platinum or of an alloy similar to that to be deposited. The electrolyte may be composed of compounds of silver dissolved in water or in alkaline cyanides, or alkalis or other bases, and may be mixed with solutions of compounds of zinc or cadmium, or of other metals of the alloy to be deposited; the electrolyte may also contain salts of the alkali and alkaline earth metals.

543,824, July 30, 1895, Henry J. Altman, of New York, N. Y., assignor of one-half to Max H. Fischer, of same place.

Relates to electrodepositing an alloy coating consisting of platinum with another metal or metals having a specific gravity of between 2.6 and 9, except manganese, antimony and chromium, which are not suited to his purposes. The preferred alloy consists of platinum and nickel, with about 1 per cent platinum; or may consist of a larger proportion, as one part platinum and three parts of nickel. The alloy deposit forms a brilliant coating resembling silver, but less liable to tarnish or corrode. The electrolyte contains the metals to be deposited as salts and is made by dissolving separately 12 ounces of nickel and ammonium sulphate in 7 pints of water, $\frac{1}{4}$ ounce of tetrachloride of platinum in $\frac{1}{2}$ pint of water, $\frac{1}{6}$ ounce of caustic soda in $\frac{1}{2}$ pint of water; the caustic soda solution is added to the platinum solution and to the mixture is added $1\frac{1}{4}$ ounces of ethylamine or its equivalent. To this mixture is then added the nickel solution and then $1\frac{1}{2}$ ounces of sodium chloride dissolved in water is added. The anode used preferably has the composition of the coating desired or may be of platinum or carbon, etc. For alloys of different composition, the proportions of the salts should be varied accordingly. In place of ethylamine there may be used any other organic base containing nitrogen, as methylamine, pyridin, etc.

563,723, July 14, 1896, Hans Alexander, of Berlin, Germany, assignor to Louis Potthoff, of Long Island City, N. Y.

This patent was reissued, No. 11,624, dated Aug. 3, 1897. It relates to plating iron or steel with a coating of zinc, as a substitute for the galvanizing of iron by molten zinc. An electrolyte containing a basic aluminium salt is made as follows: To a solution containing in 100 parts of water from 5 per cent to 8 per cent of chloride of aluminium is added sufficient metallic zinc (or tin or tin and zinc) as it will dissolve. While dissolving the solution should be kept boiling, the water evaporating being replaced. Instead of dissolving the metal chemically it may be dissolved as an anode. To the resulting solution is added from 0.2 per cent to 0.3 per cent of chloride of zinc (or of chloride of tin or of the chlorides of zinc and tin) and the boiling continued for about one-half hour. The solution may also contain an organic acid, as citric or tartaric acids. A small quantity of chloride, or sulphate, or nitrate of mercury may also be added. The deposit obtained from such a solution is said to be compact, smooth and durable.

Book Review

Laboratory Manual of Glass Blowing. By Francis C. Frary, Ph.D. Small 12mo., 57 pages, 75 cents. New York and London: McGraw-Hill Book Company, Inc.

A brief manual of instructions in the art of glass blowing that will be of value not only to beginners but also to those with some skill. The instructions are clear and concise and are well supplemented by illustrations.